

# **Design for Market-oriented Development Strategy of Bioenergy Technologies in China**

**Chief Editors   Zhang Zhengmin  
Deng Keyun  
Ralph Overend**

**China Environmental Science Press • Beijing**

# **Design for Market-oriented Development Strategy of Bioenergy Technologies in China**

**MOA/DOE Project Expert Team**

This book is written and edited based on the output of joint research project "Evaluation of Commercialization of Biomass Energy Conversion Technologies and Their Market Oriented Development Strategy" between Ministry of Agriculture of China and Department of Energy of US. The project has been supported and helped by both governments.

**Project Director:** WANG Xiwu

**Project Manager:** BAI Jinming

**Senior Consultant:** Mm. DENG Keyun

**Coordinator:** LI Jingming, DAI Lin

**Chief Directors of Chinese Expert Team:**

ZHANG Zhengmin, LI Jingjing, DAI Lin

Energy Research Institute, State Development Planning Commission

**Members of Chinese Expert Team:**

LU Zengan	Rural Energy Office, Shandong Province
WANG Yaojun	Energy Research Institute, Shandong Province
SUN Li	Energy Research Institute, Shandong Province
LUO Weihong	Rural Energy Office, Zhejiang Province
CAI Changda	Hangzhou Institute of Energy and Environmental Engineering Design
QU Feng	Rural Energy Office, Sichuan Province
JIN Yao	Rural Energy Office, Shanghai
ZENG Banglong	Sanxing Energy and Environmental Engineering Corp. Shanghai
XIONG Chengyong	Chengdu Institute of Biogas Science, MOA
WANG Gehua	Center of Energy & Environmental Protection Technology, MOA
SU Mingshan	Tsinghua University
DONG Wei	Energy Research Institute, Liaoning Province
ZHUANG Xing	Energy Research Institute, State Development Planning Commission
ZHOU Aiming	Energy Research Institute, State Development Planning Commission
SHI Jingli	Energy Research Institute, State Development Planning Commission
LIU Xiaofeng	Energy Research Institute, State Development Planning Commission
SU Zhengming	Energy Research Institute, State Development Planning Commission
HUANG Zhijie	Energy Research Institute, State Development Planning Commission

**Expert from US side:**

Ralph Overend      National Renewable Energy Laboratory, USA

**Chief Editors:** ZHANG Zhengmin, DENG Keyun, Ralph Overend

**Writers of each chapter:**

- Chapter 1 ZHANG Zhengmin, DENG Keyun
- Chapter 2 ZHANG Zhengmin, BAI Jinming, LI Jingjing
- Chapter 3 DAI Lin, LUO Weihong, QU Feng
- Chapter 4 LI Jingjing, LU Zengan, ZENG Banglong, ZHOU Aiming
- Chapter 5 ZHANG Zhengmin, LI Jingjing

Mr. WU Changlun and Mr. HE Liang have contributed to the examination and verification of the book. Mr. WANG Zhongying provided valuable materials for this book and responsible for proof reading on part of chapters. And Mr. LIU Xiaofeng has participated compiling parts of charts and figures that appeared in the book. Special thanks to them for their work.

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## Preface

I am Allan Hoffman, Acting Deputy Assistant Secretary for the Office of Utility Technologies of the U.S. Department of Energy (DOE). Recently, I led a DOE team to China to review the progress of bilateral cooperation under the Energy Efficiency and Renewable Energy Protocol signed in 1995. I must tell you how pleased I am to see that China has made considerable progress in the use of renewable energy and attention to environmental issues. I also want to congratulate China's Ministry of Agriculture (MOA) for its efforts to develop rural energy.

The MOA is the implementing agency for Annex I of the Energy Efficiency and Renewable Energy Protocol, which supports The Integrated Rural Energy Construction Program in One Hundred Counties in China. To date, DOE is pleased with joint progress made in three areas: (1) the Gansu Solar Home System project has deployed photovoltaic household systems in 300 homes and 10 schools, with another 300 systems planned by the end of 1998; (2) a comprehensive biomass technology and resource assessment is ready to be published; and (3) a socioeconomic and technology assessment of rural electrification applications is under way.

I applaud that the MOA plans to publish the reports, of which this is the first one in English and Chinese. The publication of those reports represents not only a major milestone in joint activities between the DOE and MOA, but also the foundation for continued U.S.-China cooperation with potential benefits for both countries. China is fortunate to have abundant biomass resources that can be efficiently used as a CO<sub>2</sub>-neutral power source, a critical part of China's energy sustainability and pollution prevention efforts.

The DOE would like to gratefully acknowledge the work of the MOA during the development of these publications and anticipates cooperating with the Ministry on future projects. I view our cooperation with China as very important, particularly in renewable energy projects, which can play an important part in China's response to global climate change. This cooperation will also assist China in achieving its Agenda 21 goal of sustainable energy development. Also, the potential market for U.S. renewable energy products and services in China is very large, and joint activities under the Protocol are important entry points for U.S. companies into the

Chinese market. The data in these reports will be useful to the renewables industry and serve to demonstrate the enormous potential of biomass as a sustainable resource.

A handwritten signature in black ink, reading "Allan R. Hoffman". The signature is fluid and cursive, with the first name "Allan" and last name "Hoffman" clearly legible.

Allan R. Hoffman  
Acting Deputy Assistant Secretary  
Office of Utility Technologies  
United States Department of Energy

## Preface

China, a rapid developing agricultural country, faces the double pressure of economic growth and environmental protection as it enters the 21st century. This period presents an opportunity to transform traditional ways of energy production and consumption and explore and utilize biomass energy and other renewable clean energy resources. Clean energy resources would allow for a sustainable development of the national economy, without sacrificing environmental quality.

According to an old Chinese saying, there are seven things to gather while the door is open: fuel, rice, oil, salt, soy, vinegar, and tea. This means fuel is the primary necessity for a family. At this stage in China's development, exploration and use of biomass energy resources have special and important significance.

First, China has a large population, 70% of which lives in rural areas. The annual rural energy consumption is more than 600 million tons of coal equivalent, and one-third of that amount comes from biomass resources. Second, in China, 65 million people live without electricity; 70 million experience shortages of cooking fuel; and 120 million face the threat of desertification. In addition, inappropriate exploration and utilization of biomass energy has caused ecological deterioration and soil erosion. Third, in areas with rapid economic growth, farmers have transferred their energy consumption to commercial sources such as coal, oil, and electricity, and large amounts of crop straws and stocks are now directly burned in the fields. This has not only caused resource waste and environmental pollution, but has also intensified the demand for conventional energy supplies and has caused social problems. Thus, many believe that the Chinese government should support biomass energy exploration and utilization, as it benefits nature, households, the state, and the world.

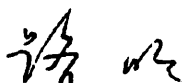
China's Ministry of Agriculture (MOA) and other relevant departments have made biomass energy exploration and utilization a priority. During the 1970s, China implemented many research projects and biomass energy utilization demonstrations. Since the 1980s, R&D to improve biomass energy conversion technologies has been listed in the National Program under key science and technology projects. Some large to medium biogas projects in husbandry farming, biomass gasification systems fed by crop straw, and biomass power generation has shown notable progress.

However, a large gap exists between the current world level and the domestic level of biomass energy exploration and utilization. This is especially true when considering the industrialization of technology and equipment. Issues remain such as how to commercialize biomass energy resource, how to accelerate the industrialization of biomass energy conversion technologies, and how to develop the huge potential market in China. These issues have drawn interest not only from China's government, science and technology, and industrial sectors, but also from the U.S. government and industrial sectors. Collaborative projects between our Ministry and the U.S. Department of Energy (DOE) to explore renewable energy demonstrate the level of interest.

It was my pleasure to meet in Beijing with Dr. Allan Hoffman, Deputy Assistant Secretary, U.S. DOE, and his delegation. We have reached a consensus that rural energy construction will advance the pursuit of sustainable development in coping with conditions in China. As we enter the new century, we will make efforts to improve the rural areas in China and throughout the world.

These three books, prepared collaboratively by MOA's and DOE's team of project experts, are the products of successful cooperation between our agencies on a study of biomass resources and biomass energy conversion technologies. I believe these research results will provide valuable reference information to government, science and technology, and industrial sectors on both sides, and will contribute to the important development of biomass energy technologies in China.

Thanks to all of you, the contributors, for your great effort.



Lu Ming  
Deputy-Minister  
Ministry of Agriculture, P.R.China

## Introduction

Biomass resource, the energy resource for human being since the ancient time, has been playing very important role along with the social development of human being. It is one of the basic elements of natural ecological system in terms of environment view point with no contribution to the global warming during its energy conversion. In China, biomass energy accounts for more than 15% in the mix of energy consumption in recent years.

Chinese government has attached high importance to the development and utilization of biomass energy resource, and conducted long and widely R&D of high and latest biomass energy conversion technology application in the National Program for Key Science and Technology Projects. Meanwhile, Chinese Government has been developing various type of collaboration and activities with foreign governments and international organizations to explore the market of biomass energy resource and its conversion technologies. On February 23, 1995, Ministry of Agriculture of People's Republic of China and Department of Energy of US signed the agreement of "For developing cooperative activities in the area of renewable energy under the hundred counties integrated rural energy development program in China between DOE, US and MOA, P.R. China" as Annex 1 under "The Protocol for Cooperation in the Field of Energy Efficiency and Renewable Energy between The DOE of US and State Science and Technology Commission of P.R. China." In 1996, under this agreement, both sides decided to collaboratively work on the issue of commercialization of biomass energy conversion technologies and their market-oriented development strategy, aimed to identify the commercial potential of advanced technology and its field, design the respectively policy and strategy for investment and market-oriented development, in order to accelerate the development of industrialization and commercialization of biomass energy technologies, through the assessment of biomass resource availability, the analysis on obstacles of technology development, and pilot research and evaluation of typical demonstration project.

The period of this joint project, divided into two phases, is 3 years. Phase 1 is from July, 1996 to July, 1998, Focusing on the availability and logistics of biomass, evaluation of the status quo and developing bioenergy technologies, case studies, and development of a market-oriented development strategy for biomass in China. It is aimed to undertake the pilot research and demonstration projects of bioenergy

technologies for phase 2 based on the output of phase 1.

In order to successfully implement this project, the Energy Research Institute of State Development Planning Commission, and National Renewable Energy Laboratory were nominated as the implementing agencies by MOA of China and DOE of US. The project expert team was established joined with the related specialists from relevant agencies, intuitions, and enterprises to conduct the different tasks in the project.

Based on the joint effort made by the experts from both sides, the work for phase 1 has been initially finished so far. In order to provide the better and efficient service to the national economic construction and society, it has been agreed by both sides to publish the reports with a bilingual text into 3 books titled "Assessment of Biomass Resource Availability in China", "Biomass Energy Conversion Technologies in China: Development and Assessment", and "Design for Market-oriented Development Strategy of Bioenergy Technologies in China". A CD-ROM would be also attached to each book with the content of the three books. The great support and assistance have been come from Department of Environmental Protection & Energy, and Department of International Cooperation, Ministry of Agriculture, Department of Industry, Ministry of Science and Technology(ex-State Science and Technology Commission) , Energy Research Institute, State Development Planning Commission, the provincial and local rural energy offices, and Department of Energy, US and National Renewable Energy Laboratory along with the project implementation. Here we would like to thank Mr. Wang Xiwu, Mr. Zhang Guozheng, Mr. Li Baoshan, Mr. Hu Yanan, Mr. Gao Shangbin, Mr. Zhou Fengqi, and Mr. Li Junfeng from Chinese side, and Mme. Lee Gerbert, Mr. William Wallace, and Ms. Christie Johnson for their great help.

## **CHAPTER 1 Brief Introduction**

### **1.1 The Position of Biomass Energy in Energy Environment System**

Biomass, in the form of firewood, charcoal and straws and stalks to provide bioenergy, has played a very important role in the history of humanity and still is essential in maintaining the social and economic fabric of society especially in rural areas. In many developing countries in Asia and Africa, biomass and bioenergy contributes over 40% of the total energy consumption. In China, in 1996 the consumption of firewood and crop stalks was equivalent to 220 Mtce, or, about 14% of the total energy consumption of the entire country, representing 34% of the energy consumption in rural area, or 59% of the rural household energy consumption. About 20 Mtce was used for village manufacturing enterprises such as small brick kilns, limestone kilns, ceramic plants and collosol plants. Firewood represented about 36% of the total biomass used with the remainder being mainly straw and stalks with a small but growing contribution from anaerobic digestion. Thus it can be seen that biomass energy resource is still a major component in China's rural energy mix.

Bioenergy is a renewable energy generated from plant biomass which is produced from solar energy through photosynthesis creating carbohydrates from carbon dioxide and water. Since the carbon in biomass is derived from atmospheric carbon dioxide, the use of bioenergy does not result in any net change in the atmospheric carbon dioxide levels and as a result the biomass and bioenergy option is carbon neutral with respect to climate change concerns. By developing more efficient biomass conversion technologies it is possible to offset the use of fossil fuels and displace fossil carbon to mitigate global climate change. In addition many biomass resources are available as residues such as sawdust, forest trimmings, agricultural straw and animal manures that can be obtained at reasonable cost and utilized in environmentally sound ways to offset their pollution impacts.

World wide the development of modern biomass and bioenergy systems is the subject of intensive research development and technology deployment (RD&TD) efforts by both governments and the private sector. Examples of RD&TD programs around the world include the: Energy Project of India; the Biomass Power and Ethanol programs of the USA; the Proalcool program of Brazil, and the extensive

programs taking place in the European Union (EU). In these the USA, Austria and Sweden, modernized biomass and bioenergy systems contribute 4, 10, and 16 percent respectively to the primary energy supply. In the USA the installed capacity for biomass power (including MSW utilization) is greater than 13 GW. In transportation the programs in Brazil and the USA are the leaders with large scale industries based on sugar cane and corn (maize) respectively.

The Government of China (GOC) has paid great attention to the development and utilization of biomass energy. Since the 1970's, a series of bioenergy research projects and demonstrative projects have been successively implemented with each 5 year plan. A large amount of outstanding research achievements and application models have emerged, and achieved considerable social and economic benefits during the process of dissemination and application. By the end of 1996, an efficient coal and firewood saving domestic cook stove had been disseminated to 170 million households. Anaerobic digestion has been introduced at several scales with over six million rural household biogas pools producing 1.6 Gm<sup>3</sup>/year of a biogas with about half the heating value of natural gas. About 600 large and medium scale biogas projects have been constructed (including biogas projects treating industrial organic waste), providing cooking fuel to 84,000 families. Reforestation and the creation of 5.4 Mha of sustainable firewood forest provides an annual firewood harvest of 40 million tonnes. Since 1980 the GOC has launched RD&TD to further improve the biomass and bioenergy technologies, notable achievements include the large and medium husbandry farm biogas engineering technology, straw and stalk gasification technology for central gas supply and refuse landfill power generation.

There is still a large gap between the state of the art in China and in the major industrialized countries of the OECD. In particular the commercialization and the deployment of China's biomass and bioenergy technologies lags those of the OECD. This report undertakes a technoeconomic analysis of 3 leading technologies in China that are close to the end of the RD&TD cycle. This analysis examines the state of the art and seeks to identify the barriers both technical and non-technical to their commercialization and deployment and discusses some of the policy tools that may be used to mitigate the effect of these barriers.

## **1.2 Basic Meaning and Assessment Principles of Technology Commercialization**

The commercialization of a technology is often seen as the final link in a development chain that starts in the laboratory and moves from a scientific research

achievement to product that is competitive in the marketplace generating increased productivity and improving the material and social circumstances of society. While the role of government is very extensive in the R&D phases through its support of universities and research institutes, the transition to the market place involves many factors outside of the government's control and requires adoption of the technology through commercialization and the involvement of customers who are mainly in the private sector.

Since technology commercialization means that technology will be sold or transferred in market as a product: we can identify the general attributes such a product has to have to be able to compete:

- (1) **Performance:** For an energy technology the primary improvements have to be in energy efficiency, environmental performance and quality and quantity of the output.
- (2) **Lifetime and Durability:** In general the major capital investment is expected to last for the anticipated duration of the project. Typically lifetimes of greater than 15 years are needed. For instance, large and medium biogas projects would generally not be less than 15 years. For stalk gasification technology, the lifecycle should be more than 15 years, based on the lifetime of the landfill a biogas power generation system should have a lifecycle generally not less than 20 years.
- (3) **Reliability and Availability:** generally reliability is a measure of the capability of the technology or product to fulfill its operational requirements when called for. A measure of this is the availability which is defined as the fraction of time in which the operation can be undertaken when the service is required. Energy systems have to have very high availabilities, typically a coal fired power station has an availability of greater than 95%, meaning that there will be less than 5% of the time of operation will have an unscheduled outage. However, to maintain this reliability there may have to be as much as 4 weeks each year in which scheduled maintenance is undertaken. Very high reliability results in less need for redundant or back up capacity in the energy systems. For instance, the civil fuel gas supply system is required to be able to supply fuel gas that can meet requirements on both quantity and quality at any time in the 8,760 hours in a year. As a result the gas plant has to install additional emergency or spare equipment to meet the requirements of residents at any time.

- (4) ***Environmental Safety and Health (ES&H)***: All systems have to prevent damage to the environment, and since the 1980s there has been an increasing emphasis on the prevention of pollution of the air, water and soil. Each state has regulations on the extent of emissions of hazardous air pollutants (HAPs) which include unburnt hydrocarbons, carbon, sulfur and nitrogen oxides as well as particulates. Systems also have to meet safety criteria - especially with respect to risks to both equipment and persons. Fire and explosion prevention are typical hazards that are regulated both by licencing authorities and the requirements of insurance companies. The health regulations range from mitigation of poisoning from hydrogen sulfide to electrical hazards and the protection of personal from exposure to heat and risks of personal injury due to falls. The development and deployment of a new technology requires considerable attention to all of these details, many of which are subject to regulation and inspection by state bodies for example in the USA, by the state and federal EPA (Environmental Protection Agency), or by OSHA (Operational, Safety and Health Administration). If a technology is intended for export, then it often has to meet the ES&H criteria of the jurisdiction into which it is being sold, sometimes these are more restrictive than those of the originating country.
- (5) ***Warranties and Performance Guaranties***: A key part of the development and manufacturing process is the maintenance of quality control and quality assurance (QC&QA) to ensure that the final product is able to meet the specified performance criteria. Many companies around the world are now adopting standard procedures described by the International Standards Organization (ISO) in both their manufacturing processes (ISO 9000 series) and in operations (ISO 14000 series). In commerce the equipment sold will have component and system level warrantanties of performance, which if they are not met will result in legal liabilities on the manufacturer. In the case of operations and maintenance similar criteria are agreed between the seller and the buyer of the technology or service.
- (6) ***Economic and Financial Parameters***: Today most systems are purchased based not on their first cost, but on their total lifecycle costs. For a given rate of return (a discount factor) the levelized cost of the service e.g. Yuan/kWh or \$/m<sup>3</sup> of gas can be computed. For major state and federal infrastructure projects such as a hydro-electric and irrigation scheme the discount rate is usually a social discount rate that will reveal the value of the project to society as a whole. For an enterprise the calculation will include taxes, capital write down (depreciation), and will reflect the degree of direct investment (equity) and borrowing (loans or bonds) requirement. For an owner to invest their own money, they often have an

opportunity cost of capital that defines the needed financial rate of return on their equity, while the cost of bank loans or the servicing of bonds comes at lower cost.

These six considerations both generalize the basic content and conditions of technology commercialization, and at the same time can be used as assessment principles for commercialization development. We have generalized these principles into 4 groupings:

- *Technology Characterization*: which embraces the functional characteristics of the technology (including maturity, stability, reliability, safety and lifecycle considerations);
- *Economic feasibility*;
- *Social acceptability*;
- *Performance and Warranties*.

Our technology characterization uses four stages to describe the state of development of the technology.

- 1) research and development, often with theoretical trial research
- 2) pilot demonstration, in which there is scale up and increased experience in order to examine its economic and technological practicability
- 3) pre-commercial deployment, that is, the technology is basically mature, and has met many of the conditions of commercialization, but requires some incentives to encourage its adoption especially where price signals are not appropriate so that it requires subsidy from government
- 4) full commercialization, a stage in which the technology is deployed entirely according to market mechanism.

We do not subscribe to the view that technology development is a linear process however. Thus a system such as the straw gasification for cooking gas development may be at a pre-commercialization and demonstration stage but will embody components that are already commercial such as gas meters and gas burners that have been developed through either town's gas or the biogas programs.

## **CHAPTER 2 Assessment of Commercialization Development of Biomass Energy Technologies**

### **2.1 Assessment of Commercialization Development of the Technology in Biogas Project on Husbandry Farms**

#### **2.1.1 Technology characteristics**

Biogas a mixture of carbon dioxide and methane with a heating value of  $25 \text{ MJ/Nm}^3$  is produced from animal excrement under the action of anaerobic bacteria. The process of anaerobic digestion accomplishes three goals simultaneously: pollution elimination; energy generation, and the integrated disposal of animal excrement and waste water. With careful design a biogas project can provide a multi-level and integrated utilization of a large scale biomass energy resource. Extensive RD&TD in China since the 1980s has resulted in the deployment of nearly 600 medium and large installations that demonstrate these benefits.

Generally there are five distinct process steps or stages that are required:

- (1) pretreatment - including an acid treatment tank, pH adjustment tank, humidity adjustment and solid-liquid separation. These are important in guaranteeing stable operation of the biogas project
- (2) the anaerobic digester - digesters such as AF (Anaerobic Filter) and UASB (Upflow Anaerobic Sludge Blanket) have been widely used, and developed into high performance systems
- (3) biogas handling - the collection, storage, transportation and distribution system, including such equipment as the gas-liquid separator, purification and desulfurization, gas storage, gas transportation and biogas combustion, etc., which exert key functions in guaranteeing high grade fuel to users and its high efficiency utilization
- (4) liquid residue post-treatment equipment - fermented residue precipitation pond, aerobic and anaerobic treatment facilities, and residue discharge facilities, etc., which are essential in meeting the environmental regulations for water discharge to the environment
- (5) solid residue or sludge treatment system - including equipment for solid residue drying after fermentation, solid-liquid separation and the production of grain

fertilizer and feedstuffs, which can improve economic qualities of the whole project and helps to realize integrated resource utilization.

A major advance in making anaerobic digestion economic has been the increases in the gas production rate per unit volume of the digester. The higher this number, the lower the capital investment that has to be made. Typically unmixed digestors at ambient temperatures produce  $0.1 \text{ m}^3$  of biogas per  $\text{m}^3$  of digester volume. Current medium scale units on husbandry farms can produce biogas at a rate of  $0.4 \text{ m}^3/\text{m}^3$  per day. Even greater gas production rates are shown in some recent biogas shown in the case studies tabulated in Table 2.1. The reduction in pollution that is obtained with anaerobic digestion has increased the social acceptability as described below.

The economic performance of the integrated treatment of animal husbandry wastes includes the following benefits:

- (1) By pre-separating the unutilized feedstuffs in animal excreta it is possible to recover 100-1,000 yuan for each tonne of renewable feedstuff recovered. This has relied on advances in solid-solid separation applied to the incoming slurries.
- (2) The solid residue after fermentation can be dried and pelletized and used as a high grade organic fertilizer for fruit orchards and horticultural flower production, yielding an income of 80-100 yuan per tonne.
- (3) The liquid residue can be used directly as a farm fertilizer, for swine and fish production and in hydroponic culture.

The experience to date has demonstrated that the majority of the installed equipment has reliable properties, and has relatively long lifecycle. Since the principal facilities (anaerobic digestion tower, etc.) in most biogas projects are generally built with materials having characteristics as anti-acid, anti-alkali, anti-erosion, and high strength. i.e. ferroconcrete, they are effective equipment for disposing corrosive wastes such as excrement waste water. For example, the  $8,350 \text{ m}^3$  biogas digesters built on Shanghai Changjiang Farm in 1984, and the  $200 \text{ m}^3$  biogas digester built on Hangzhou Fushan Husbandry Farm in 1989, are still in normal operation. It is expected that the ferro-concrete systems will have at 15-20 year lifetimes.

### 2.1.2 Economic feasibility

There are very completely commercial large and medium scale biogas projects in China, Thus the data on design and operation, including project feasibility analysis and the assessment report at the stage of project establishment, required in the light

**Table 2.1 Biogas yield level of some biogas projects on husbandry farms in China**

Classification	Raw materials	Technology type <sup>a</sup>	Equipment scale (m <sup>3</sup> )	Ferment temperature (°C)	Biogas yield rate (m <sup>3</sup> /m <sup>3</sup> .day)	Remark
According to raw materials used for ferment <sup>b</sup>	Chicken excrement	Fill Flow	2×160	35-50	2.4-4.0	Lab research: At 50°C biogas yield can reach 5-6 liter/liter.
		Fill Flow	100	50	3.0-3.6	
		UASB AF	200	30	1.35-2.08	
		UASB	128	23-25	1.0	
	Pig excrement	USR	300	35-38	1.7-2.2	MBB Company from Germany utilizes 500 m <sup>3</sup> two-step ferment, with medium temperature gas yield rate 5 m <sup>3</sup> /m <sup>3</sup> .day.
		UASB AF	2×130	16-33	0.8-1.3	
	Ox excrement	USR	120	35	1.5	VEGGER Biogas Experiment Farm of Finland mainly uses ox excrement for ferment at 50 , its gas yield rate can reach 5 m <sup>3</sup> /m <sup>3</sup> .day
According to regions <sup>c</sup>	Averaged in the whole country				0.4	
	Including					
	Beijing				0.23	
	Hebei				0.36	
	Shanghai				0.80	
	Jiangsu				0.24	
	Zhejiang				0.59	
	Hubei				0.35	
<b>Detailed Case Study<sup>d</sup></b>						
Shenzhen Liantangwei Pig Farm	Pig excrement	UASB AF	2×130	15-33	1.46-2.0	
Shenyang Masanjia Pig Farm	Pig excrement	UASB	2×1,000	9-13	0.3	
Zhejiang Fushan Husbandry Farm	Pig excrement	Integrated UASB	500	18-28	0.94	
Zhejiang Fushan Husbandry Farm	Chicken excrement	Integrated UASB	200	18-28	1.24	
Hangzhou Hen Experiment Farm	Chicken excrement	Two-step ferment	First step 250, second step 500	First step 30 , Second step 18-28	1.0	
Shanghai Xinghuo Farm	Mainly ox excrement	Two-step ferment	2,700	28-30	0.78	

(Continued)

Shanghai Changjiang Farm	Pig and chicken excrement	UAF	5,350	Normal temperature	0.22-0.78	
No.1 Farm of Zhejiang Province	Ox excrement			Nearly medium temperature	1.5	

Note: a UASB refers to Upper Flow Anaerobic Sludge Bed, AF refers to Anaerobic Filter, USR refers to Upper Flow Solid Reactor.

- b calculation based on the data from China Biogas (1995-1997).
- c calculation based on the data in China Rural Energy Yearbook (1997).
- d calculation based on the Investigation Materials.

of commercialization is scarce. We can only take advantage of the research fruits achieved by some scientific and technological experts (see Table 2.2) to describe the economic feasibility on commercialization.

From Table 2.2, it can be seen that the economic benefits mainly come from the following aspects: i) sale of biogas; ii) grain organic fertilizer selling; iii) producing renewable feedstuffs; iv) residue used in farms to offset purchases of chemical fertilizer; v) residue used as substitute feedstuffs to increase output and income in aquiculture, and vi) avoided environmental protection fines.

All of these projects have required a large capital investment, and we have calculated that the integrated benefits have been very different, in that some are good, while some are poor. Generally project economic qualities are closely related to local price levels. For example, the biogas project on Shanghai Xinghuo Farm has relatively better economic benefits, mainly because of the income from the relatively high biogas price which is nearly 5 times of that of Hangzhou Fushan Husbandry Farm in Zhejiang Province.

We have also found a large effect of project scale on the economic performance. For animal husbandry that will only support anaerobic digestors at the 100-1000 m<sup>3</sup> scale, which is to say small and medium size operations, it is not possible for them to be profitable and commercial operations.

### 2.1.3 Social acceptability

As an integrated project combining both energy environment benefits, the environment functions of the biogas projects are quite outstanding, which has been welcomed and accepted by society. The environmental advantages are composed of the following functions:

- (1) A large amount of animal excrement and waste water are treated, which alleviates environmental pollution to a certain degree. It is predicted that over 6 million tons of organic excrement waste water is disposed by large and medium biogas projects in the whole country in a year.
- (2) The harmful materials in excrement waste water have been largely eliminated. Table 2.3 shows the elimination rate of harmful materials of various operating digestion facilities.
- (3) Though indirect it has been found to eliminate diseases and insect pests. Each husbandry farm which has built a biogas project, has had obvious improvements in sanitation and environmental conditions that mosquitoes and flies are greatly reduced. See Table 2.3.

#### **2.1.4 Integrity of technology guarantee and quality service system**

Biogas projects are based on systems engineering which combines traditional construction and modern biological technologies, and the benefits depend on a guarantee of integrated technology service and operation of an industrialized system. Through the extensive RD&TD efforts of China and the widespread dissemination and application of biogas project technology a large number of trained scientists and technologists have gained extensive practical experience. Specialist teams to provide design, construction and service have been formed since the Eighth Five-year Plan. Biogas project service companies have been successively established in some regions to provide users with extensive service including project design, construction, production and operation, operations management, and technology training, etc.. For example, Since its establishment five years ago, the Hangzhou Municipal Environment and Energy Engineering Company has formed a full service organization taking anaerobic digestion from scientific research, proving trials and experiments, to project contract, design and construction, and management and training. This is leading to extensive commercial development of large and medium biogas projects.

Several provinces have established corresponding operations regulations and industry standards, for anaerobic digestion and biogas production. Hubei Province has established the following standards: Design Standards for Large and Medium Anaerobic Biogas Project (E B/NE24-88), Quality Check and Examination Standards for Large and Medium Anaerobic Biogas Project (E B/NE39-89), and Construction and Operation Regulations for Large and Medium Anaerobic Biogas Project (E B/NE40-89), etc., which not only has generated practical effects on accurately guiding the development of biogas project, but also is important for

<i>Basic parameters</i>						
	Hongzhou Hen Farm	Biogas project on Hangzhou Xizi Husbandry Farm	Biogas project on Fushan Husbandry Farm	Biogas project on Shanghai Xinghuo Husbandry Farm	Biogas project on Shenyang Masanjia Husbandry Farm	A pig farm in Beijing
1 Scale of husbandry farms	200,000 chickens	10,000 pigs	3,000 pigs, 130,000 chickens	2,000 cattle	20,000-25,000 pigs	15,000
2 Scale of biogas project (m <sup>3</sup> )	750	500	700	2,700	2,000	1,000
3 Total investment of project (10,000 yuan )	95.0	281.45	77.15	912	200	263.2
4 Total operation cost of project (10,000 yuan )	6.0	21.59	5.03	73	21.00	25.0
5 Total benefit of project (10,000 yuan )	12.75	65.5	11.4	198	61.67	75.6
Including: Biogas selling (10,000 yuan )	6.75	20.5	6.66	144.1	10.95	57.60
Unit price (yuan/m <sup>3</sup> )	0.25	0.80	0.25	1.20	0.50	0.80
Biogas power generation 10000 yuan						94.61
Electricity price (yuan/kWh)		0.8				0.50
Grain fertilizer (10,000 yuan)	6.0	33	4.75	4.7	49.30	18.0
Unit price (yuan/ton)				100		
Renewable fertilizer (10,000 yan)		including grain fertilizer		26.9	including grain fertilizer	
Unit price (yuan/ton)				1,000		
Avoided environmental protection fines (10,000/y)		12		15.4		
6 Basic discount rate (%)	10.0	10.0	10.0	10.0		10.0
7 Life cycle of the project (year)	21.0	21	21			21
<i>Assessment result</i>						
1 Financial Net Present Value NPV (10,000 yuan)	-37.65	-73.17	-24.38	7.8	62.53	74.12
2 Financial Internal Rate of Return(%)	2.67	4.53	4.28	12	15.07	14.54
						17.40

<i>Basic parameters</i>		Hongzhou Hen Farm	Biogas project on Hangzhou Xizi Husbandry Farm	Biogas project on Fushan Husbandry Farm	Biogas project on Shanghai Xinghuo Husbandry Farm	Biogas project on Shenyang Masanjia Husbandry Farm	A pig farm in Beijing	A pig farm in Beijing
1	Scale of husbandry farms	200,000 chickens	10,000 pigs	3,000 pigs, 130,000 chickens	2,000 cattle	20,000-25,000 pigs	15,000	30,000
2	Scale of biogas project (m <sup>3</sup> )	750	500	700	2,700	2,000	1,000	2,000
3	Total investment of project (10,000 yuan)	95.0	281.45	77.15	912	200	263.2	440.00
4	Total operation cost of project (10,000 yuan)	6.0	21.59	5.03	73	21.00	25.0	41.70
5	Total benefit of project (10,000 yuan)	12.75	65.5	11.4	198	61.67	75.6	142.13
	Including: Biogas selling (10,000 yuan)	6.75	20.5	6.66	144.1	10.95	57.60	11.52
	Unit price (yuan/m <sup>3</sup> )	0.25	0.80	0.25	1.20	0.50	0.80	0.8
	Biogas power generation 10000 yuan							94.61
	Electricity price (yuan/kWh)		0.8					0.50
	Grain fertilizer (10,000 yuan)	6.0	33	4.75	4.7	49.30	18.0	36.0
	Unit price (yuan/ton)				100			
	Renewable fertilizer (10,000 yan)		including grain fertilizer		26.9	including grain fertilizer		
	Unit price (yuan/ton)				1,000			
	Avoided environmental protection fines (10,000/y)		12		15.4			
6	Basic discount rate (%)	10.0	10.0	10.0	10.0		10.0	10.0
7	Life cycle of the project (year)	21.0	21	21			21	21.0
<i>Assessment result</i>								
1	Financial Net Present Value NPV (10,000 yuan)	-37.65	-73.17	-24.38	7.8	62.53	74.12	206.67
2	Financial Internal Rate of Return(%)	2.67	4.53	4.28	12	15.07	14.54	17.40

**Table 2.3 Effects of eliminating harmful materials in large scale biogas projects on husbandry farms**

	Normal temperature complete mixing type	Medium and low temperature complete mixing type	High efficiency anaerobic digester
Total solid elimination rate TS	>50%	>70	80-90
COD elimination rate	60%	70-75	80-90
Death of coliform	$10^{-2}$ - $10^{-1}$	$10^{-2}$ - $10^{-1}$	$10^{-1}$
Death rate of ascarid eggs	100	100	100

normalizing biogas project market and improving commercialization of biogas project. Despite these advances there is a continuing need for increased standards and performance criteria to be developed not only at the state but also the national level.

The analysis shows that China's biogas projects pass the basic criteria for commercialization and can be viewed as in a stage of pre-commercialization. Key improvements that would increase the commercialization potential include: increasing the gas yield rate; developing a commercially viable post-treatment system; improved equipment quality and construction practices. By reducing investment costs, strengthening the technology guarantee and service system, and increased use of standards and regulations it will be possible to create favorable conditions for the complete commercialization of biogas projects.

## **2.2 Assessment of Commercialization Development of the Technology of Crop Straw Gasification for Central Gas Supply**

### **2.2.1 Technical characteristics**

Biomass gasification refers to the chemical reaction process in which substances such as C, H, etc., in biomass material are converted into effective components such as CO, H<sub>2</sub>, CH<sub>4</sub>, etc., under the action of gas media (such as air or pure oxygen, etc.). There also existed biomass gasification technology in the ancient times. As early as the 1950s, there existed examples of taking wood as material to generate gas to drive motors and supply power for rural irrigation appliances in China; while taking straw as material and centrally supplying cooking gas fuels for rural households has not happened until the recent 10 years. Although this technology started late, it develops rapidly. At present, many demonstrative projects have been built, and there are several dozens only in Shangdong Province. Practice indicates that this technology is

becoming mature. In the following, we take straw gasification technology for central gas supply developed by Shangdong Energy Research Institute under Shangdong Provincial Academy of Sciences as an example to further illustrate this technology.

Firstly, a system which is rather complete while simple and practical has already been developed for straw gasification technology for gas supply.

The whole system consists of three parts: biomass gasification station, fuel gas distributing system and indoor appliances for households. Main equipment of the gasification station is a XFF type fixed bed down-draft biomass gasification device, which consists of a feeder machine, a gasifier, a fuel gas purifier and a fan. Fuel gas distributing system is composed of gas container and pipeline network. Active carbon fuel gas purifier, fuel gas flowmeter and low heat value gas stove are equipped indoors. The system is compact in structure, simple and practical. Besides fan, there is no other high speed rotating appliances in the system and therefore it is safe and reliable.

Secondly, generated fuel gas can reach the quality demand of civil fuel gas basically. Currently, there are two models of XFF type biomass gasification sets: XFF-1000 Model and XFF-2000 Model. The former generates 200 m<sup>3</sup> of fuel gas per hour and can supply gas for 100-130 households; the latter generates 500 m<sup>3</sup> of fuel gas per hour and can supply gas for 130-250 households.

For details of its basic characteristics, see *Biomass Energy Conversion Technologies in China: Development and Evaluation*.

This kind of technology has already had gas-supplying ability of certain scale and can basically fulfill the demand of domestic gas fuels by residents in natural villages. Although the heat value of the generated fuel gas is very low, only about 1/3 of the standard heat value (14.7kJ/m<sup>3</sup>) of China's artificial coal gas, the stable combustion of straw fuel gas is not a problem with the use of supporting low heat value gas combustion stove for this technology. The CO content of gas generated in some demonstrative equipment is high sometimes, while the risk can be avoided with the standard design, manufacture, installation and operation of the system.

Thirdly, the technical characteristics of specially designed and manufactured low heat value fuel gas stove have reached the basic demand of domestic coal gas stove. According to measurement, combustion efficiency of such stove can be as high as 55.2%, air tightness, CO content in fume, stability of flame and heat power, etc., of

the stove have all reached the standard of domestic coal gas stove.

However, there are still a series of problems associated with this technology that need to be solved or further improved, such as: problem of further reducing tar and impurity content of the fuel gas; problem of improving design and thus preventing gas leakage and assuring the system's safety; problem of strengthening the monitoring of equipment's and system's operation and enlarging the adaptability to fuels, etc., in order to establish a stable base for the technology's industrialization and commercialization.

### 2.2.2 Economic feasibility

Up to now, research on the economic analysis of central gas supply system utilizing straw gasification technology has just begun. Just from the results of researches conducted by Energy Research Institute under State Development Planning Commission (SDPC) and Institute for Techno-Economics and Energy System Analysis under Tsinghua University respectively, the conclusions are basically consistent, i.e.: from the viewpoint of financial evaluation, IRR of this technology is less than 6%, far less than China's social average discount rate. Calculation and analysis results of research conducted by Energy Research Institute are shown in Table 2.4. For details, see the book *Biomass Energy Conversion Technologies in China: Development and Evaluation*.

**Table 2.4 Results of economic analysis of XFF-2000 type central gas supply system using straw gasification technology**

Main parameters	Financial evaluation	Economic evaluation
number of households supplied with fuel gas	216	216
heat value of fuel gas (kJ/m <sup>3</sup> )	5,200	5,200
gasification efficiency (%)	73	73
total project investment ( 10,000 yuan)	38.79	38.79
annual operating cost ( 10,000 yuan)	2.30	3.23
annual gas output ( 10,000 m <sup>3</sup> )	38.88	38.88
gas price ( yuan/m <sup>3</sup> )	0.1	0.3
annual income (10,000 yuan)	3.89	10.11
NPV (10,000 yuan )	-4.52	9.15
IRR (%)	5.9	17.4

Table 2.5 shows the results of an analysis, conducted by Institute for Techno-

Economics and Energy System Analysis under Tsinghua University, of the sametype system. The results indicate that one household needs to pay 1.13 yuan for fuel gas one day, if fuel gas price is 0.226 yuan/m<sup>3</sup>, the cost price. This cost is 7-8% higher than the coal gas expense of urban households (assuming that one household consumes 1.5 m<sup>3</sup> coal gas one day and gas price is 0.7 yuan/m<sup>3</sup>), and it is obvious that the price is unacceptable for peasants of common income level.

**Table 2.5 Analysis of central gas supply cost using straw gasification technology**

main calculating parameter	indexes
number of households supplied with gas	200
gas output of digester ( m <sup>3</sup> /hr)	400
total project investment ( 10,000 yuan)	44.51
annual operating cost ( 10,000 yuan)	2.93
system service lift (yrs)	15
discount rate (%)	10
gas output of straw ( m <sup>3</sup> /kg)	2
straw price ( yuan/kg)	0.06
using price of gas per unit ( yuan/m <sup>3</sup> )	0.226

### 2.2.3 Social acceptability

Although straw gasification technology is not economically beneficial when evaluated financially, it has bright prospect when considered from long-term and the country's viewpoint. With straw gasification technology, biomass resource distributes dispersally in rural areas can be fully utilized, so the technology is an important measure to achieve modernization of domestic fuels in rural areas.

The popularization and application of straw gasification technology not only will provide an efficient way of thoroughly solving the problem of stacking straw randomly, reduce the pollution caused by the incineration of straw and avoid the hidden fire trouble that can be caused by the random stacking of straw, but also will promote the improvement of cooking energy structure in rural areas, village and family sanitary conditions.

With the development of rural economy, the proportion of fossil fuels such as coal, petroleum, etc., in cooking energy of rural residents becomes larger and larger, so the popularization and application of straw gasification technology will undoubtedly provide an effective way of substituting fossil fuels and alleviating the pollution caused by the vast use of fossil fuels.

The development of straw gasification technology can improve cooking energy

structure in rural areas, greatly lighten working intensity and save cooking time. According to investigations, the cooking time of housewives who have used straw fuel gas has decreased from 3 hours a day in the past to 1.5-2 hours. This can provide women the time to attend other activities.

With the development of straw gasification technology, not only local renewable energy resources can be fully utilized, but also the consumption fund that was used to buy commercial fuels from other areas in the past can now be changed into construction fund of local areas. This can markedly promote the development of rural economy of local areas and increase employing positions. Some experts expect that if 200 central gas supply systems using straw gasification technology can be installed in one province each year, manufacturing enterprises, technology service companies and project construction enterprises with certain scales can be formed and several hundreds or even one thousand employing positions can be newly created.

#### **2.2.4 Integrity of technical assurance and quality service system**

This technology is still in an experimental and demonstrative period, and technical assurance and service system has not yet been completely formed. Progresses that have been made include:

(i) Technical problems associated with system and equipment design, manufacture and installation have been basically solved, and technical ability of standard design, manufacture and installation of central gas supply systems using straw gasification technology, used for natural villages, has basically formed. (ii) A series of provincial technical standards and regulations have been formulated. For example, *Technical Conditions for Normal Pressure Fixed Bed Biomass Gasification Sets*, *Design Criterion of Small-scale Biomass Fuel Gas Supply System*, *Construction and Inspection Criterion of Small-scale Biomass Fuel Gas Supply System in Rural Areas*, *Technical Criterion of the Operation and Maintenance of Biomass Fuel Gas Supply System in Rural Areas*, etc., have already been formulated in Shandong Province. These documents are helpful to the normal demonstration of this technology and have made some essential preparation for the large-scale application of it.

Above-mentioned analysis indicates that gasification and gas supply technology using crop straw as material is one of the fastest developing biomass energy utilization technologies in recent years and it is suitable to the actual conditions of China's rural areas and thus has a broad developing prospect. Whereas, this

technology is not economically mature currently, further experimental tests are needed and some problems related with the system's safe and stable operation still need further research. At present, efforts on R&D and experiment and demonstration should be further strengthened to make the technology more perfect and complete, construction and operation mode using market mechanism should also be summarized and discussed, to promote the technology into market as soon as possible.

## **2.3 Assessment of Commercialization Development of Refuse Landfill Power Generation Technology**

### **2.3.1 Technical characteristics**

Garbage landfill refers to that garbage is carried to selected sites and is pile up layer-by-layer according to previously designed procedures. Organic materials in the garbage will be decomposed into gases, mainly  $\text{CH}_4$  (methane), under the condition of no oxygen. These gases can be stored in container through special channels and can be used for power generation and heat supply.

Landfill is one of the urban barrage disposal methods. Besides this technology, there are still others such as compost, incineration power technology, etc. While this technology has, comparatively, the characteristics of simpleness and low cost, and energy can also be recovered, so it is welcomed by various countries across the world. Up to now, 2,247 and 175 garbage landfill fields have been built up in USA and Europe respectively and there are 4817 fields in the whole world. As much as 5.142 billion  $\text{m}^3$  of garbage methane, equivalent to 2.396 million tons of petroleum, can be recovered in landfill fields every year. Garbage landfill methane power technology is already a mature one in foreign countries.

In China, the situations are different. Up to now, few researches on urban garbage disposal technologies have been conducted in China. A few institutions such as Chinese Academy of Sciences have conducted work on this technology and the middle test of a  $160\text{m}^3$ -scale technology has been completed.

Practice of experiment, demonstration and project construction is also limited. Projects that have already been built up and basically accord with the demand of landfill technology are mainly located in the following areas: (i) Qingshan Region of Baotou City; (ii) Asuwei in Changping County, Beijing; (iii) Laogang of Shanghai City; (iv) Tianziling of Hangzhou; (v) Zaikeng of Zhongshan City, Guangdong

Province; (vi) Datianshan of Guangzhou; (vii) Xiaping of Shenzhen; (viii) Mengyuan of Nanchang. Foreign technologies are used in a few of these landfill fields.

According to statistics, there are 61 landfill fields in America which use internal combustion engines to generate power, and the total installed capacity has reached 340 MW when the installed capacity of internal combustion turbines is also added; in Europe, internal combustion engines are used for power generation in 50 landfill fields, unit capacity of these engines can be as high as 0.4-2 MW, while small ones can be installed in a container and moved from one landfill field to another. The current efficiency of landfill methane power technology is 1.68-2 kW/m<sup>3</sup>.

In China, research on methane power technology is mainly focused on internal combustion engine technology, which is usually a simple alternation of gasoline engine or diesel engine. While there is a lack of research on the thermal characteristics of revised engine and production capacity of special methane engine has not yet been formed.

Therefore, from the viewpoint of technology, scale production system has not yet been formed in China and the technology is still in an experimental and demonstrative period.

### **2.3.2 Economic feasibility**

The whole process of methane production from garbage landfill must be considered comprehensively when calculating economic benefits of garbage landfill power projects. The problem should be considered firstly is the garbage landfill itself, because the scale of garbage landfill field will decide methane yield, gas production efficiency and methane extraction ratio. Some people conclude that methane power projects with garbage volume above 1 million tons, area more than 10 has and landfill depth above 10 m have good investment payback rate. The design of methane recovery and leach liquid recovery system is also very important. If the utilization of methane is considered at the very beginning and horizontal extraction pipelines and leach liquid recovery systems are constructed, both methane production efficiency of garbage and methane extraction ratio will be high, even can be higher than 75%. Besides these, power price is also an important factor.

In policy aspect, if preferential taxation and loan policies can be given by the government and environmental laws and regulations can be implemented, economic

benefits of garbage methane power projects will be obviously improved.

For Tianziling Landfill Power Project in Hangzhou (for details see, *Biomass Energy Conversion Technologies in China: Development and Evaluation*), the average power price is 0.0538 US\$/kWh (0.438 yuan/kWh) and investment payback rate of the project is 14.8%. This indicates that such projects can be economically attractive to some extent.

### **2.3.3 Environmental characteristics**

Garbage landfill power projects are aimed to solve environmental pollution problems, so their operation will solve some main environmental problems caused by garbage landfill fields, for example:

- (1) Green house gas emission can be mitigated. By methane power projects, CH<sub>4</sub> can be mitigated. The mitigation of 1 ton CH<sub>4</sub> is equal to the mitigation of 25 tons of CO<sub>2</sub>. This can alleviate green house gas effect.
- (2) The collection of garbage landfill gases is favorable to the safety and health of people working in landfill fields. Atmospheric quality can be improved and the probability of fire disaster and gas explosion in landfill fields or areas nearby can also be decreased.
- (3) The recovery of landfill gases will greatly lighten the foul smell caused by gases released from landfill fields.

### **2.3.4 Integrity of technical assurance and quality service system**

Due to the lack of practical projects, China's foundation in this aspect is very weak and need urgent strengthening. It can be seen from above-mentioned that garbage landfill power technology is still in the primary period of development and there is still a long way to go before commercialization, while the developing tendency is strong and the prospect is broad.

## **CHAPTER 3 Barriers in the Process of Commercialization of Biomass Energy Technologies**

As other renewable energy technologies, biomass energy conversion technologies also are faced with many barriers and problems in their commercial development. To say generally, these barriers and problems mainly come from aspects such as resources condition, industrialization condition of technology, economic feasibility of technologies, financing environment, market potential and the government's policy guidance in promoting the commercial development of these technologies, the public's environmental consciousness and dissemination of information about consumers' consumption tendency, etc.(see figure 3.1). Whereas, it can be seen from the current development situation of biomass conversion technologies that they are faced with different barriers, due to their different technical processes, different developing stages and different social orientations.

### **3.1 Barriers for Commercialization of the Technology in Biogas Project on Husbandry Farms**

#### **3.1.1 Resource Condition**

At present, there are more than 6,000 large- and medium-scale milk cattle, pig and chicken husbandries in China and they discharge more than 0.8 million tons of feces and waste water per day, only 10-15% of which is treated with biogas technology. Furthermore, there will be a rapid increase in the livestock amount in China's large- and medium-scale husbandries by year 2000 and 2010 (see Table 3.1), according to expert estimation. Obviously, this is very advantageous to the development of large- and medium-scale biogas project technology.

**Table 3.1 Forecast of amount of China's livestock and poultry (1995-2010)**

	Year 1995	Year 2000	Year 2010
cattle ( 10,000 head)	13,206.0	16,615.2	23,783.3
pig ( 10,000 head)	48,501.0	65,834.0	99,894.6
commercial chicken (10,000 head )	336,606.24	470,435.4	843,575.8

Data source: *Assessment of Biomass Availability in China*, MOA/U.S. DOE Project Expert Team, 1998.

However, there are also disadvantageous factors for the development of biogas projects when resource condition is considered. The first is the small centralized

livestock amount. At present, there are more than 10,000 husbandries with fairly large scale, while the amount of livestock raised in these husbandries only accounts for 9-43% of that of the whole country. The second is the small scale of husbandries. According to statistics, among all the scaled husbandries, there are only 500 milk cattle fields with annual raising amount more than 500, about 5% of the whole number, and more than 2000 pig farms with raising amount more than 500, only about 20% of the total number. Too small raising scale is disadvantageous to the popularization of biogas project technology.

### 3.1.2 Industrialization condition for the technology

From the viewpoint of technological industrialization, there are now still some main problems, as listed below.

- (1) There are no uniform standards for the design and construction of large- and medium-scale biogas projects, certificate standards for construction are not complete, and all these have resulted in the lack of filtering and identifying ability to related technologies for most enterprises.
- (2) Automatic level still needs to be increased. Currently, most of China's large- and medium-scale biogas projects are operated manually or semi-mechanically, so problems such as pool explosion, biogas leakage, pipeline blocking, etc., can be caused when they are improperly operated, and these problems will affect the normal operation of biogas projects.
- (3) Some key technological equipments, including solid-liquid separator, desulphurizing equipment, biogas generator and control system, etc., have not yet reached the requirement of industrialization and commercialization and this is also an important factor affecting the popularization and development of biogas technology.
- (4) The production and supply of culture have not yet been industrialized.

Whether technical support and service system is complete is another standard judging whether a technology or product can be commercially operated. Up to now, related local operating rules and professional standards have already been formulated in areas with many biogas projects, while when seen from the formulation of state level rules and standards, there are no formal state level technical regulations with real authority and there are no concerned technology detecting institutions, although research was conducted during the "Eighth Five-Year Plan" period on the standardization of biogas project technology, such as *Designing Rules for Large- and Medium-scale Biogas Projects, Construction and Checking*

*Standards for Large- and Medium-scale Biogas Projects, Technical Manual for Large and Medium-scale Biogas Projects and Research on Analyzing and Evaluating Methods of Economic Benefits of Large- and Medium-scale Biogas Projects.* Moreover, compared with the complete network of professional technical service of common goods, technical service network of biogas project technologies has not yet been formed, so the incompleteness of technical supporting and service system is a factor restricting the market development of biogas projects.

### 3.1.3 Economic characteristics of the technology

It can be seen from the analysis in chapter 2 that the poor economic benefit of biogas projects is an important barrier restricting the commercial development of the technology. The following two reasons are responsible for the poor economic benefits of biogas projects.

The first factor is price. Behind price is the problem of operating mechanism. Take Star Farm Biogas Project in Shanghai as an example. In this project, price is formulated on the base of market economy and according to value principles. In year 1995, the price of biogas of this farm was 1.2 yuan/m<sup>3</sup>, equivalent to that of coal gas or natural gas, and the demand amount was also very large, so the income from biogas sell accounted for about 73% of the project's total benefits, and the IRR of the projects was 12%. If the prices increase or decrease by 10%, varying range of the project's IRR is between 11-15% and the project still is economically feasible. While for biogas project in Fushan Husbandry, biogas supply is treated as a welfare undertaking and the price of biogas is only 0.25 yuan/m<sup>3</sup>, so IRR of the projects is only 4.28% (for details, see Table 2.2). It can be seen from this that price will directly affect the economic benefits of biogas projects. As commercially operated enterprises, large- and medium-scale biogas projects in poultry and livestock husbandries should not be ordered to sell their products (such as biogas, fertilizer, etc.) at certain prices, on the other hand, the prices should be formulated by the enterprises themselves according to their own operating demand. If the local communities and governments want the enterprises to sell related products at welfare prices, the subsidy for such price differences should be paid from the community's or government's budget on "social welfare" and should not be born by the enterprises.

The second factor is the project's scale. Because the scale of China's biogas projects in husbandries is usually below 100-1,000m<sup>3</sup> and belongs to medium and small scale, economic benefits of such projects are rather poor. Therefore, the scale of biogas

projects or the scale of husbandries directly restricts the economic feasibility of this technology.

#### **3.1.4 Financing problem**

Fund shortage is an important factor restricting the development of large-scale biogas projects. Furthermore, cost of the project is very large, even larger than that invested in the husbandry itself. This has restricted the utilization of this technology in common husbandries.

Generally, gas production amount of large-scale biogas project is 1,000-2,000 m<sup>3</sup> per day, and the total project investment is 3-10 million yuan. Gas production amount of medium-scale biogas project is 500-1,000 m<sup>3</sup> per day, and the total project investment is 0.8-3 million yuan. Developing tendency in the future is large-scale and central husbandry, so, great attention will be paid to the development of large-scale biogas projects after year 2000. Although some amount of interest discount has been given to large- and medium-scale biogas projects by concerned departments such as State Economic and Trade Commission (SETC) and Ministry of Agriculture, etc., as well as local fiscal authorities, at present, bank loan is still the main financing resource of China's large- and medium-scale biogas projects and the banks use evaluation methods for common industrial projects to evaluate these projects. For biogas projects, their social and environmental benefits are more prominent than their economic benefits and these benefits have not been materialized into monetary form, so the results of conventional financial evaluation usually leads to the failure of loan evaluation. Therefore, the main barriers for biogas projects in financing aspect are as follows:

- (1) Evaluation methods for conventional industrial projects are not suitable for renewable energy projects such as biogas projects, of which the environmental benefits are prominent than economic benefits;
- (2) Single financing pattern;
- (3) Financing channels are not smooth.

#### **3.1.5 Policy environment**

##### **(1) *Investment policy.***

At present, there is no clear investment policy that encourages the development of large- and medium-scale biogas projects and some currently existing policies (such as there is special interest discount loans for renewable energy projects organized by

SETC) have not been actually implemented due to the lack of proper evaluation methods for this type of projects.

**(2) *Price policy***

Currently, most of the biogas prices belong to welfare ones and due to the lack of concerned bases and measures in formulating guiding price by the government, biogas projects cannot become one real part of the market.

**(3) *Tax policy***

The government has given very limited preferential taxation policy to biogas projects which have not the ability to be run commercially while have obvious social and environmental benefits. For example, the basic rate of value added tax in China is 17% currently, while the rate is 13% for biogas projects. Even in such a case, stimulative effect for renewable energy projects with large initial investment cannot be achieved.

**(4) *environmental policy***

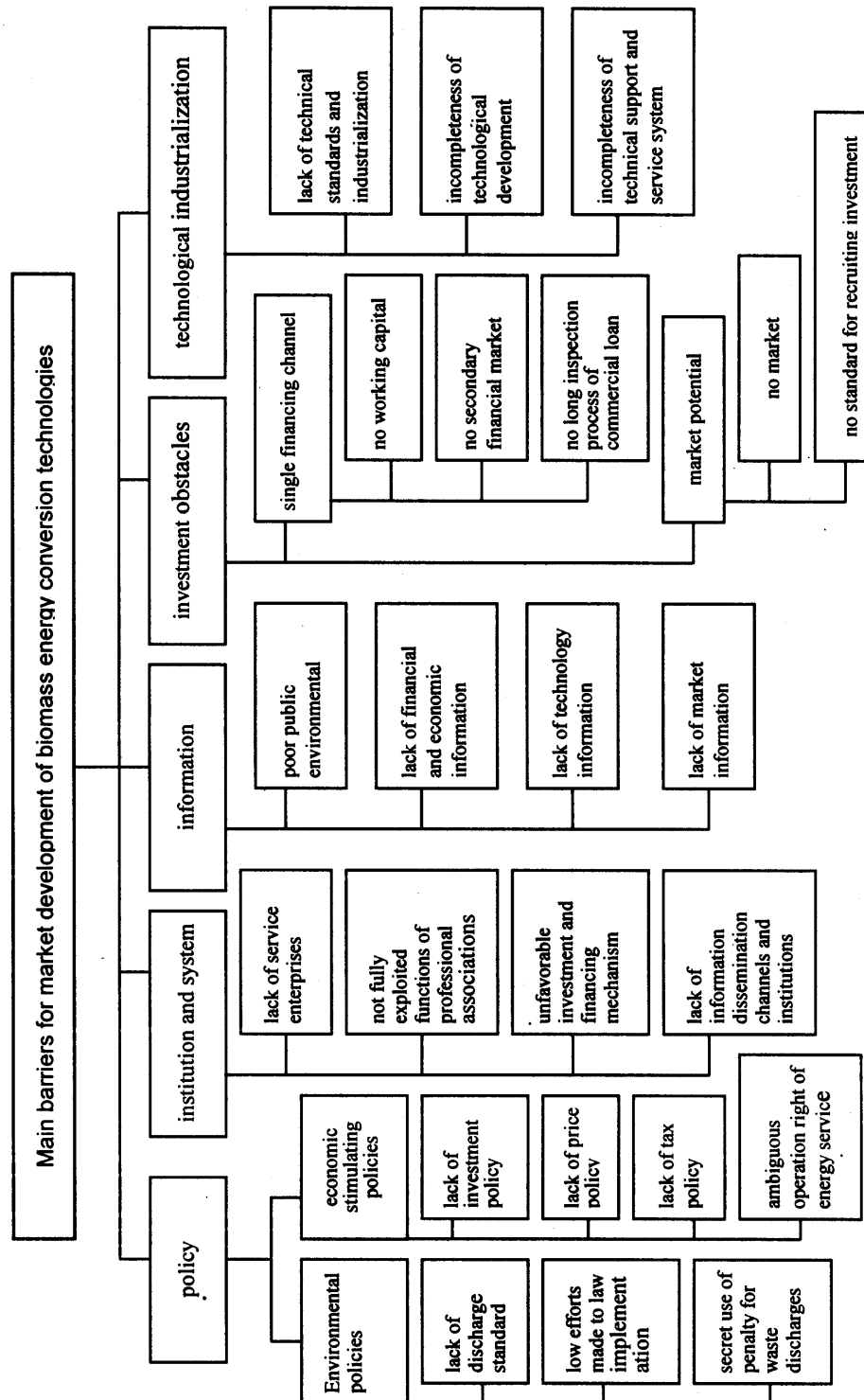
Environmental pollution problems caused by the development of large-scale husbandries cannot be neglected. Take Beijing as an example, the current pollution is very serious, COD (chemical oxygen demand) of the discharged soil water from large-scale pig husbandries is 53 times higher than that required by the standard, BOD (biologic oxygen demand) is 76 times higher than that required by the standard and SS (suspended substance) is 14 times higher. Penalties charged to husbandries by environmental protection authorities are different in different areas, but more severe punishment will be the tendency. Therefore, how to utilize environmental protection policy to promote the development of large and medium size biogas projects and how to use charges for disposing pollutants more properly is an important policy needs to be studied and formulated by the government.

### **3.1.6 Barriers for information dissemination**

Mainly include the following aspects:

- (1) Lack of channels of technical information dissemination, lack of comprehension to the technology by consumers;
- (2) Lack of environmental protection education, including teaching materials in education scope, environmental education of managerial personnel at all levels, especially personnel of financing system, theoretical education of sustainable development, etc.;
- (3) Lack of introduction of foreign mechanism of utilizing economic measures to promote the disposal of organic waste water discharged by husbandries.

Figure 3.1 Main barriers for market development of biomass energy conversion technologies



### **3.2 Barriers for Commercialization of the Technology of Crop Straw Gasification for Central Gas Supply**

#### **3.2.1 Resource condition**

China is a large agricultural country with a large crop yield and rich straw resources. According to investigations, the whole country's crop straw yield in 1996 was 705 million tons and except some was used as feed for stock raising, fertilizer, industrial raw materials and peasants' domestic fuel, 107 million tons had no use. This has provided a rich resource for straw gasification technology. Other forecasts indicate that by year 2000, China's acquirable straw amount (refers to amount of straw that can be used as fuel) will reach 150-160 Mtce. It can be seen that resource potential is very large.

However, there still exist unfavorable factors in resource aspect. The first is that the resource distributes very dispersedly, so it is difficult to collect and transport it and certain cost is needed. The second is the difficulty in storing it: in the south there exists problem of preventing water and damp; in the north, there exists problem of preventing fire.

#### **3.2.2 Conditions for technological industrialization**

Straw gasification technology is now still in a developing and experimental stage and the following technical problems need to be solved urgently.

- (1) The content of CO is rather high and cannot completely reach the standard of fuel gas used by urban residents, and fuel gas standard for rural use has not yet been formulated;
- (2) The disposal of tar and cleaning of gas still need to be improved;
- (3) Reliability and safety of the whole system need to be confirmed;
- (4) Regulations for quality inspection and construction of central gas supply projects have just been put forward in Shangdong Province and state level regulations and standards have not yet been formulated.

#### **3.2.3 Economic characters of the technology**

Barriers in this aspect mainly include:

**(1) *High initial system investment***

The main market of straw gasification technology lies in rural areas. For a village with 200 households, it is rather difficult for it to invest several hundreds of thousands of yuan at one time to build a gas supply system. It can be seen from project's sensibility analysis (national economic analysis) that if initial investment increases by 20%, IRR of the project will decrease from 17.4% to 13.1%. So initial investment will greatly affect the project's economic benefits.

**(2) *Too low fuel gas price***

The current gas price of gas supply system utilizing straw gasification technology still belongs to welfare price and is only 0.10 yuan/m<sup>3</sup>; while the current value cost of fuel gas is 0.22 yuan/m<sup>3</sup>. When compared with price of LPG with equivalent heat value (3 yuan/kg), the price of straw fuel gas should be 0.23 yuan/m<sup>3</sup>. Financial IRR of the project corresponding with this price is 19%, so the project has good financial feasibility. It is obvious that fuel gas price is the key factor determining whether this kind of project is economically feasible.

**3.2.4 Investment**

From the actual situations of more than 50 demonstrative villages in Shangdong Province, it can be seen that most of the construction fund comes from the governments at all levels (from the provincial government to county governments to villages). Because the technology is now still in a developing and demonstrative period, determinate financing channels and patterns have not yet been formed up to now.

Market potential mainly depends on two factors: conditions of technological industrialization and the peasants' income. According to the analysis of sample survey of peasants, the Pearson correlation coefficient between per capita average income of households and attitude to the construction of gas station is 0.816, which shows that there exists obvious positive linear dependency relation between the two. Therefore, the commercial process of this technology also depends on the development of rural economy in related areas.

**3.2.5 Policy guidance**

At present, the technology is still in a demonstrative and developing period when seen from its developing situation, and the country's policies of price, taxation, etc., are still incomplete. From the aspect of environmental protection, the problem of

straw consumption is not only a problem of solving rural residents' cooking energy, but also more important a problem of assuring the atmospheric condition of peripheral areas of cities and normal communications and transport. For example, in Zhandian Region of Shangdong Province, because on-the-spot incineration of straw has affected the normal operation of speedways, the local government has decided to charge 6,000 yuan penalty when one *mu* of straw is incinerated. This has not only promoted the application and dissemination of straw gasification technology, but also brought the commercial operation of this technology with external benefits. It can be seen from this that environmental protection is a key factor deciding the process of the technology's market development.

### **3.3 Barriers for Commercialization of Refuse Landfill Power Generation Technology**

To say generally, barriers for the commercial development of garbage landfill power technology in China are mainly as follows:

- (1) Collecting ratio of China's urban garbage is low and utilizable garbage resource is limited; furthermore, the landfill fields are small and nonstandard, which is unfavorable to the commercial exploitation and utilization of garbage;
- (2) Garbage landfill power technology has just started in China and is not mature, and further experience and examination is needed;
- (3) China's economic ability is limited and can only fulfill the demand of garbage collection and clearing, and cannot fulfill the need of garbage disposal. This is a main factor restricting the development of technology;
- (4) Due to the lack of concerned stimulative and restrictive policies, foreign investors cannot be attracted to invest in garbage disposal projects. This is also an important reason of the slow development of garbage landfill power technology.

## **CHAPTER 4    Market Potential and Analysis of Biomass Energy Technologies**

Research and analysis of market potential is one of the preconditions of commercialization development of technology. The technology without market potential has no future development, so it is necessary to conduct special research and analysis on the market potential of the technology.

How big is the market scale of the technology using biomass energy? Where is it allocated in the market? In fact, the market potential is affected by many factors. For example, the technology market of domestic husbandry biogas project is not only affected by the development condition of itself, but also impacted directly by the development conditions of the domestic fowl and livestock breeding industry, while the development of the domestic fowl and livestock breeding industry is determined by the development of national economy and the development mode of stock raising, and the main factors include the requirement of renewable development of society, economy and environment, resident's income level, and the demand tendency to the high quality energy, and so on.

Based on above, the research project will proceed with the analysis of local energy supply and demand, then give priority research to relation between the change of resident's income level and the demand level to high quality energy, subsequently to analyze the market potential in related three technologies.

### **4.1    Trend Analysis of Rural Area Energy Consumption**

#### **4.1.1    Changes of energy consumption structure in rural areas**

Since 1980, Chinese economic changes have made rural economy develop quickly, the quantities, varieties and structure of energy consumption in rural areas has changed greatly. Table 4.1 and Table 4.2 describe the change in detail. Two aspects are obvious: the first one is, with the development of agriculture industry and villages and towns industries, the energy consumption quantities in rural production increased highly. In 1980, in rural areas the energy consumption used by production was only 67,000,000 ton coal equivalence, but in 1987, the energy consumption in rural areas reached 188 million ton coal equivalence, which is 2.18 times of what

**Table 4.1 Changes of Energy Consumption in China Rural Areas**

Unit: Mtce

Item	Year 1980	Year 1987	Year 1996
<b>The total energy consumption in China</b>	<b>831.7</b>	<b>1,146.2</b>	<b>1,550.3</b>
The Total Rural Areas Energy Consumption	328.0	517.7	636.72
Percent of rural energy consumption occupies the total	39.4	45.17	41.07
<b>Commercial energy usable in rural areas</b>			
Coal and coal produce	65.1	183.2	274.23
Petroleum produce	15.0	24.6	49.88
Electric power	19.0	30.0	93.31
Total commercial energy	99.0	237.8	417.43
<b>Non-commercial energy</b>			
Firewood	112.0	147.3	99.33
Straw and stalk	117.0	132.6	119.97
Total non-commercial energy	229.0	279.9	219.30

Note: (1) electric power is accounted by the quantities of standard coal converted from the average coal consumption of the heat – engine plant in that year.

(2) Data in the table come from *Chinese Statistical Yearbook, 1997*; *China Rural Energy Yearbook, 1997*; and *Implementation and Management of Rural Energy Integrative Construction*.

**Table 4.2 Changes of Rural Areas Energy Consumption Construction in China**

Unit: Mtce

Items	Year 1980	Year 1987	Year 1996
<b>Total Rural Areas Energy Consumption</b>	<b>328.0</b>	<b>517.7</b>	<b>636.72</b>
<b>Energy used by production</b>			
Coal and coal products	28.0	123.6	173.24
Petroleum products	14.0	22.7	45.17
Electric power	16.0	25.0	64.18
Total commercial energy	58.0	171.3	282.59
Straw and stalk	9.0	17.0	16.34
Total	67.0	188.3	298.93
<b>Living energy</b>			
Coal and coal products	37.0	59.6	100.99
Petroleum products	1.0	1.9	4.71
Electric power	3.0	5.0	29.13
Total	41.0	66.5	134.83
Firewood	103.0	130.3	82.99
Straw and stalk	117.0	132.6	119.97
Total	220.0	292.9	202.96
Total living energy	261.0	329.4	337.79

Notes: (1) electric power is accounted by the quantities of standard coal converted from the average coal consumption of the heat – engine plant in that year.

(2) production energy includes energy consumption in agriculture production and energy used by township enterprises production.

used in 1980. In 1996, the energy consumption used by production is about 300 million ton coal equivalence, which is 4.46 times of what used in 1980. And 1.6 times of what used in 1987. Of the energy consumption used by rural production, 95 percent is commercial energy, and the coal is the main source, which occupies 57.8 percent of the total energy consumption, and the second the electric and petroleum product, the biomass energy occupied only 5 percent.

The another reason is that the continuous increase of commercial energy in rural living energy consumption and the persistent decrease of non-commercial energy, and the coal consumption is increased double, petroleum products and electric power consumption increase 2-8 times, firewood and straw and stalk decreased 15 and 10 percent.

According to the point of social development, these changes should be viewed as a type of advance. Interpretation by technology, the usage of firewood and straw and stalk is still primitive and out of date in current rural areas, it not only is inconvenient, but also pollute the environment. With the development of society, it is an inevitable trend for people to seek energies more convenient and cleaner.

#### **4.1.2 Increase of economic capability and the demand growth for high quality energy**

With the development of economy and the increase of farmers' income, the need for high quality energy and commercial energy increased, too. The Table 4.3 and Table 4.4 separately show the situation of revenue and expenditure and the energy consumption fee of farmers in recent years. From the two tables we can see that from 1990 to 1996 the farmers' income increase double; at the same time, the energy consumption fee increased dramatically, namely 70 yuan per person and year in 1996, 200% more than 1990. In areas where economy developed quickly and the people's income were high, the farmers had a higher expenditure in energy consumption. For example, the electricity fee in Shanghai and Zhejiang Province is almost 2 times or even more than the average level of China; On the contrast, in areas where economy develop slowly and the income is low, the electricity expense is low. For example, in Sichuan Province, the electricity expense is only 1/3 of that of Shanghai. 4.5 lower than the average point of China.

Figure 4.1 and Figure 4.2, Figure 4.3 analyze the development of high quality energy used for cooking in Sichuan Province, Shandong Province, Zhejiang Province and whole country local areas, Table 4.5 specifically analyzes the rural resident living energy consumption construction and level according to the separate income level.

**Table 4.3 The base situation of rural resident revenue and expenditure**

	Year 1990	Year 1995	Year 1996
The total number of investigation (family)	66,960	67,340	67,610
Average total income (Yuan)	990	2,338	2,807
Average net income per capita (Yuan)	686	1,578	1,926
Average cash income per capita (Yuan)	796	1,882	2,309
Average cash expenditure per capita (Yuan)	741	1,767	2,137

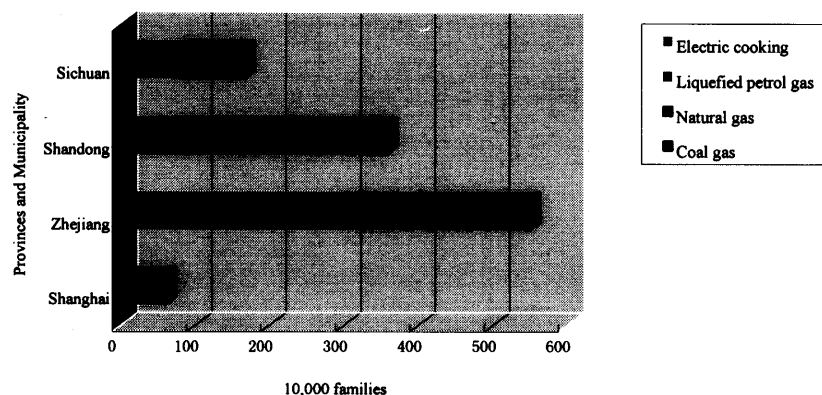
Data source: National Statistics Bureau Agriculture Investigation Team

**Table 4.4 The fuels and electricity power expenditure situation of some rural areas in 1996**

Unit: Yuan / person year

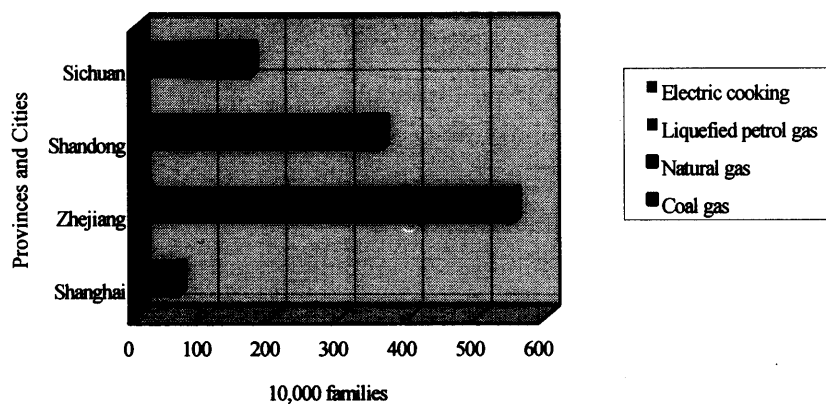
Areas	electricity expenditure	fuels					
		subtotal	coal	coal products	straw and stalk	charcoal	other
Total	17.70	53.17	11.79	4.39	30.64	0.43	5.92
Shanghai	49.43	39.19	0.01	0.18	10.04	-	28.96
Zhejiang Province	31.67	40.25	0.25	3.98	15.94	0.13	19.95
Shandong Province	18.73	93.14	17.18	9.28	52.91	0.17	13.6
Sichuan Province	13.20	37.79	8.47	0.38	27.26	0.22	1.46

Data source: National Statistics Bureau Agriculture Investigation Team

**Figure 4.1 Rural areas high quality energy use trend**

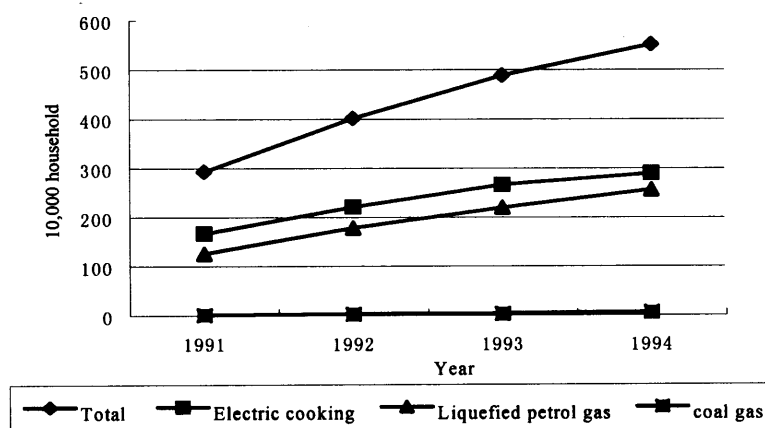
	Shanghai	Zhejiang	Shandong	Sichuan
Coal gas	10.41	5.84	32.30	41.50
Natural gas	0.00	0.12	4.58	42.63
Liquefied petrol gas	52.12	256.68	284.44	12.49
Electric cooking	289.07	38.03	71.66	71.66

**Figure 4.2 Sichuan Province, Shandong Province, Zhejiang Province rural areas high quality cooking energy comparison (10,000 families)**



	Shanghai	Zhejiang	Shandong	Sichuan
Coal gas	10.41	5.84	32.30	41.50
Natural gas	0.00	0.12	4.58	42.63
Liquefied petrol gas	52.12	256.68	284.44	12.49
Electric cooking		289.07	38.03	71.66

**Figure 4.3 1991-1994 Zhejiang Province rural areas resident high quality energy consumption trend**



**Table 4.5 Living energy consumption per family grouped by farmer's income(1997)**

Farmer's income	<1,500 Yuan	4,500-6,500 Yuan	6,500-9,000 Yuan	9,000-14,000 Yuan	>14,000 Yuan	Average
Sample Numbers	64	67	85	137	140	493
Electricity (kWh)	204.8	273.3	335.4	504.5	641.3	443.8
Liquefied petroleum gas (kg)	21.6	28.7	68.5	71.2	103.3	67.6
Petroleum products (kg)	12.1	18.4	35.8	180	229.5	80.4
Coal (kg)	876.1	999.0	1,318.7	1,556.3	1,042.5	925.0
Biogas (m <sup>3</sup> )	-	3.6	12.7	56.5	83.3	42.0
Firewood/straw and stalk (kg)	86.7	256.1	199.7	168.8	152.4	170.7
Total energy consumption (kgce)	807.1	1,033.2	1,350.9	1,584.4	16,454.4	1,185.9
Proportion of commercial energy (%)	94.6	87.6	92.6	94.7	95.4	92.8

Materials from: research group sample survey statistical information

The figures and tables above prove again the following point:

- (1) Energy Consumption has close relation to income, namely: the higher advanced economy and the income, the higher the energy consumption is. The Chart 4.5 shows that the energy consumption of farmer family that has revenue above 14,000 yuan is about 2 times of that whose family revenue is below 1,500Yuan; etc.
- (2) The higher the family revenue, the much proportion of the ratio of commercial energy among living energy consumption per family;
- (3) The more the family revenue, the much need for high quality energies, such as liquefied petroleum gas, biogas and electricity, and the higher the energy consumption.

The experts think that in order to meet the demand for national economy development the next century and to improve the energy construction, in addition to decreasing the discharge of greenhouse gas and protecting the environment, the number of biomass energy used during 2010 and 2020 is accounted about 290 million tce. But we can see from the current situation, the biomass energy consumption will decrease according to the contradiction between the strong hope to use high quality energy because of the farmer's increasing income and the lagged biomass energy technology which can not keep up with the real demand. In order to improve this condition, it is necessary to take measures quickly to accelerate the

steps of biomass energy technology.

## **4.2 Market Potential and Analysis of the Technology in Biogas Project on Husbandry Farms**

### **4.2.1 Summary**

The residents' living condition is improved notable from 1980. In order to supply the market abundant meat, fowl, eggs, milk products and so on, the government put in practice the "vegetable basket" project throughout China. In addition to encouraging farmers to increase the food stuff production, the government also encourage to set up large and medium size intensified domestic animal farm. It is said according to the statistics materials, there are about 10,000 relative scale domestic animal farms in China, which have 35 million pigs that account for 9.1 percent of the total number of China, 277,000 milk cows that account for 43.4 percent of the total number of China, 352 million chicks that account for 15 percent of the total number of China,

A large number of intensified domestic animal farms were set up, which supply enough meat, fowls, eggs, milk to the market, at the same time, domestic husbandry discharge a great deal of domestic animal excrement and water mixture that pollute the environment. If the excrement and water mixture are handled with anaerobic fermentation technology, the environment will be improved and the biogas and some organic fertilizer can be extracted, thus the goal to use biomass resources comprehensively will be realized, which lead to the good feedback among energy, economy and environment protection.

To implement the domestic excrement biogas project, it is necessary to invest a large amount of money. Specially, other factors, for example: if the resident nearby need biogas, or what is the possible price of biogas, are bound to take effect on the development of biogas project. So it is necessary for supplying materials for decision-making to investigate and analyze the market potential of setting up domestic animal farms and implementing biogas project.

### **4.2.2 The Investigation and Analysis of Large and Medium Size Domestic Husbandry Farms**

In 1997, the research project specially investigated 94 domestic animal farms in Shandong Province, Shanghai, Zhejiang Province, Sichuan Province, some basic information is as following:

**(1) Group by the areas and the ownership**

The domestic animal farms investigated mainly located in Shandong Province, where there are 66 farms accounting for 70% of all farms investigated; Shanghai and Zhejiang Province are next to Shandong Province, where separately there are 13 and 10 farms accounting for 14% and 11%, there are 5 farms in Sichuan Province which account for 5%. Among all these domestic animal farms investigated, there are 30 farms belonging to ownership by the whole people, accounting for 32% of the all farms investigated, 31 farms belonging to private, accounting for 33%, 21 farms belonging to collective ownership, accounting for 22%, 12 other types of farms, accounting for 13%.

**Table 4.6 Group by ownership**

	Farms Investigated	Public Ownership	Collective ownership	Private Ownership	Public & Collective	Collective & Private
Shandong Province	66	13	15	27	3	8
Shanghai	13	8	4	0	0	1
Sichuan Province	5	1	1	3	0	0
Zhejiang Province	10	8	1	1	0	0
Total Number	94	30	21	31	3	9

**(2) Group by the breeding type in farms**

The breed type composition of farms investigated is as following table:

**Table 4.7 Group by breed types in farms**

	Farms Numbers	Pig Farms	Cattle Farms	Chicken Farms
Shandong Province	66	41	11	25
Shanghai	13	12	0	2
Sichuan Province	5	4	1	1
Zhejiang Province	10	11	0	1
Total Numbers	94	68	12	29

Notes: some farms breed two kinds of domestic animals, so the total numbers is less than the sum of all farm numbers

**(3) Group by the scale of farms**

The design scale and actual scale of the farms investigated is shown as Table 4.8, we can see that the design scale of all pig farms is above 6,000 pigs, the large scale cattle farms is above 10 thousand, little scale cattle farms has about several hundred of cattle, the little scale chicken farms breed 50 thousand chickens, large scale chicken farms has about 1 million chickens, but the actual scale is commonly less than the design scale because of the changes of demand, and even much less.

**Table 4.8 Group by the scale of the farms**

	Pig Farms		Cattle Farms		Chicken Farms	
	Average Design Scale (10 <sup>3</sup> )	Average Actual Scale (10 <sup>3</sup> )	Average Design Scale (10 <sup>3</sup> )	Average Actual Scale (10 <sup>3</sup> )	Average Design Scale (10 <sup>4</sup> )	Average Actual Scale (10 <sup>4</sup> )
Shandong	7.8	4.9	9.4	6.2	85.27	6.97
Shanghai	13.0	11.4	27.0	1.1	11.67	9.67
Sichuan	6.4	7.6	0.15	0.11	10.00	12.00
Zhejiang	9.4	5.1	0.6	0.55	5.00	5.00

#### 4.2.3 Analysis of Market Potential to Develop Biogas in Domestic Animal Farm

##### (1) Group by the current treatment of the excrement from the domestic animal farms investigated

**Table 4.9 Treatment and usage condition of excrement and water mixture**

	Shandong	Shanghai	Sichuan	Zhejiang	Total
<b>1. Sell as fertilizer</b>					
Sell numbers (10 thousand tons) in 1997	4.22	0.43	0.01	0.33	4.99
price(Yuan / ton)	93	46	0	30	
<b>2. As materials for biogas fermentation</b>					
Actual quantity used in 1997 (10 thousand tons)	6.72	1.79	0.91	1.20	10.62
Ration of Quantities used to the whole (%)	35	46	65	40	38.6
<b>3. Natural discharge</b>					
Quantities of actual discharge in 1997 (10 thousand tons)	8.26	1.68	0.48	1.41	11.89
Total (10 thousand tons)	19.20	3.90	1.40	3.00	27.50

The excrement treatment condition in those domestic animal farms investigated is shown as following table (Table 4.9). The total excrement was 270,000 tons in 1997, and 49,900 tons were sold as fertilizer, which accounted for 18.2%; 106,200 tons were used as the materials for the biogas fermentation project established which accounted for 38.6; the other 118,900 tons are naturally discharged, which accounted for 43.2%.

The reason of the utilization ratio of excrement as materials for biogas in Shanghai, Zhejiang is relatively higher than that of other areas is that the high environment requirement and the high price of the coal and liquefied petroleum gas in these areas. It is shown as following Table 4.10.

**Table 4.10 The actual prices of commodities in areas investigated**

	Shandong	Shanghai	Sichuan	Zhejiang	Average
Domestic coal price (Yuan/ton)	317	400	132	376	306
Domestic electrovalence (Yuan/kWh)	0.75	1.19	0.49	0.52	0.74
Liquefied petroleum gas price (Yuan/pot)	43	52	47	48	48

To estimate the market potential of biogas project by the natural discharge quantities, the market potential is only 43.2%, the investigation showed that the selling of excrement in developed areas became more difficult than before, the table above shows that 43% of excrement are naturally discharged in Shanghai, only 11% are sold. So with the development of economy, the market potential will increase from the aspect of seeing excrement as resource. When excrement are completely sold nothing, the development potential in Shanghai will reach 54%.

**(2) Analyze according to the environment requirement**

According to the investigation and statistics, the excrement discharge fee for domestic animal farms in 4 provinces and cities is shown as Table 4.11, the enterprises ordered to handle their pollution in scheduled time are shown as Table 4.12. The investigation shows that at the present time the charges for disposing pollutants are only retrieved from the domestic animal farms at environs in big cities, and there is nothing required for the domestic animal farms at outer suburbs. The farms charged with disposing pollutants only account for 10%, and the farms are not charged for disposing pollutants account for 90%. According to the present environment requirement, the market of biogas project set up is only 10%. If the environment requirement becomes more strictly, for example, to charge the domestic animal farms at outer suburbs for disposing pollutants or designate deadline to handle their disposing pollutants, the market potential will expand.

**Table 4.11 The condition of charges for disposing pollutants for domestic animal farms in four provinces and cities**

	Shandong	Shanghai	Sichuan	Zhejiang	average
No charges for disposing pollutants	65%	46%	60%	90%	65%
Charges for disposing pollutants	9%	15%	0%	10%	10%
Unknown	26%	38%	40%	0%	26%

**Table 4.12 If the enterprises are designate a deadline to handle the pollution**

	Shandong	Shanghai	Sichuan	Zhejiang	average
Yes	8%	46%	0%	10%	13%
No	92%	54%	100%	90%	87%

**(3) *Analyze the market potential according to economic benefits***

The economic benefits of biogas project include 3 aspects. The first is that it can decrease the charges for disposing pollutants such as excrement and water mixture. The benefits in this aspect exist only in areas where there are charges for disposing pollutants, and doesn't exist in areas no charges for disposing pollutants. The second is that the biogas can be used as fuels for living or boiler or can be used to generate electric power for farm itself, and the surplus electricity can be sold, too. This special benefit is high in areas where the energy price is high, and low in areas where the energy price is low. The third is that dregs and residue and in biogas pool can be sold as fertilizer. According to the established biogas projects, the benefit difference is little, if the energy price is high and the biogas dregs and biogas fluid can be sold. If the biogas can be sold as the market price of liquefied petroleum gas, the investment can be recovered in 5 years. But according to the present established biogas projects, the benefits are not notable because the biogas is used only for the farm staff and the price is low and the dregs and residue are also used by farm itself. So the benefits calculate as the market price, the market potential to set up biogas projects should be fixed in areas where energy price is high, such as in Shanghai、Zhejiang Province and Shandong Province, which account for 94% of the total.

**(4) *Analyze comprehensively***

to the domestic animal farms in rural areas, the investment to set up a biogas project is relatively large fund. Compared with a medium scale domestic animal farms with simple facilities, the investment of a biogas project maybe exceed the investment for the farm. Thus, although it is true to set up a biogas project can make high environment benefits, and the farmers are also willing to use high quality biogas and even the higher benefits in areas where the energy price is high, many domestic animal farms have no intentions to set up biogas project. Table 4.13 makes further analysis for domestic animal farms to handle their excrement and water mixture.

The investigation shows that about 58 domestic animal farms will sell the excrement, which account for 62% of the total, and 22 farms think that the benefits from excrement are notable; 31 farms plan to set up biogas project to handle excrement, which account for about 33%, the main reason is that it can relatively completely handle the problem of polluted water discharge to set up biogas project. Only 5 farms (about 5%) plan to do nothing with the excrement discharge because of the large investment. The investigation also shows that when the domestic animal farms set up biogas project, if the investment can accept large financial assistance, 52 farms which account for 55% express the idea of setting up biogas project; in addition, when the environment protection need charge double for disposing

pollutants(at the present time some areas charge 1 Yuan/ton for disposing pollutants), 37 farms which account for 39.4% express the idea of setting up biogas project.

**Table 4.13 The design for handling excrement and water mixture**

	Shandong	Shanghai	Sichuan	Zhejiang
<b>1. Sold as fertilizer</b>	<b>62%</b>	<b>62%</b>	<b>50%</b>	<b>57%</b>
Reasons:				
Need for farmers nearby	42%	23%	30%	27%
Notable economic benefits	20%	38%	20%	30%
<b>2. Handle excrement by biogas project</b>	<b>33%</b>	<b>36%</b>	<b>40%</b>	<b>30%</b>
Reasons:				
Biogas project can relatively completely solve the problem of polluted water discharge	20%	22%	20%	22%
Set up biogas projects can decrease charges for disposing pollutants	11%	14%	15%	8%
Short of fuels and electricity in local areas	2%	3%	5%	0%
<b>3. Do nothing and discharge naturally</b>	<b>5%</b>	<b>2%</b>	<b>10%</b>	<b>13%</b>
Reasons:				
Charges for disposing pollutants can be afforded	1%	0%	3%	0%
The excrement and water mixture can be handle by the farm land	1%	0%	2%	3%
There is enough energy and electricity in local areas	1%	1%	0%	5%
To set up biogas project need too much money	2%	1%	5%	5%

The materials above show that the market potential of biogas project is up to the economic benefits and raising investment. The prerequisite is that setting up biogas project can make better economic benefits, including saving charges for disposing pollutants. If no benefits or low benefits many of the farms still choose to sell the excrement as the main way. The words above analyze this viewpoint. Under various circumstances, the market potential for domestic animal farms to set up biogas project is show as Table 4.14.

**Table 4.14 Market potential collective analysis**

(large and medium domestic animal farms may take biogas project under various condition)

	Total of 4 Provinces and cities		Total in China	
	Farms number	Ration of the total (%)	Farms number	Ration of total (%)
biogas project products under the market price	88	94	6,494	89
Excrement can not be sold directly		54	3,731	51.3
Market potential calculated if natural discharge		43.2	2,985	41.0
If give financial assistance to investment	52	55	3,800	52.2
If double charge for disposing pollutants	37	39.4	2,722	37.4
The farmers express the intention to do so	28-38	30-40	2,073-2,763	28-38

Note: The large and medium scale domestic animal farms are 7273 in China, and 2078 of them are cattle farms(>100), 2045 of them are pig farms(>500), 3150 of them are chicken farms(above 5000), and presume that 5% farms had set up biogas projects.

### 4.3 Market Potential and Analysis of the Technology of Crop Straw Gasification for Central Gas Supply

#### 4.3.1 Summary

The straw output in China is about 700 million tons each year. 355 million tons can be used as energy resource, in addition to industry raw materials, animal husbandry fodder and fertilizer. At the present time, about 250-300 million tons can be used as fuels for warming and cooking. With the rural economic development and the increase of farmers' income, more and more farmers want to use convenient and clean commercial energy, especially high quality gas fuels and electricity power. So in Shandong Province, Hebei Province, Sichuan Province and other areas some farmers burn the straw directly in farmland. What they did not only waste resource, but also pollute the air environment. It is a good way to decompose the straw and make combustible gas for farmers cooking and warming carried by pipes, it makes full use of biomass resource, and meets the farmer's need for high quality energy, and shows a important tendency for energy supply in Chinese rural areas in recent years.

But the straw gasification projects need a great deal of investment, and many factors,

such as: management, charge, price difference between gas and other energies, will affect the development of straw gasification project. To supply support to decision, it is necessary to investigate and analyze the market potential to set up straw gasification project.

#### 4.3.2 The basic condition of farmers investigated

In order to analyze the market potential for intensified gas supply with straw gasification technology, in 1997, 50 farmers at Tangwan village and Liugiao village, Chengxiang Town, Xiaoshan City, and Xinhua village, Ningwei Town were investigated, the basic information is shown as following table:

Village Name	Tangwan Village	Xinhua Village	Liugiao Village
Average person number per family	3.7	3.1	2.7
Average income In 1996 (Yuan/person. year)	3,988	3,445	4,419

The straw utilization condition by farmers above is shown as Table 4.15. Because the areas where the farmers were investigated have a relatively advanced agricultural economy, and the annual income is high, almost each farmer family has coal oven, and 90% farmers have liquefied petroleum gas oven.

**Table 4.15 The straw utilization condition with farmers investigated**

Village Name	Straw Utilization Type	The Constitution of Straw Utilization (%)		
		Rice straw	Wheat straw hood	Cotton straw
Tangwan Village	As fertilizer in fields	19.6	0	0
	As fuels	22.3	52.5	86.7
	As fodder	4.3	0	0
	To be sold	16.4	36.2	3.3
	<b>No usage</b>	<b>37.4</b>	<b>11.3</b>	<b>10.0</b>
Xinhua Village	As fertilizer in fields	16.2	0	0
	As fuels	38.8	52.5	86.7
	As fodder	0	0	0
	To be sold	33.8	36.3	3.3
	<b>No usage</b>	<b>11.2</b>	<b>11.2</b>	<b>10.0</b>
Liugiao Village	As fertilizer in fields	13.6	0	0
	As fuels	55.0	60.0	72.5
	As fodder	0	0	0
	To be sold	27.1	21.7	0
	<b>No usage</b>	<b>4.3</b>	<b>18.3</b>	<b>27.5</b>

**Table 4.16 Farmers living energy condition**

Energy Structure	Tangwan Village	Xinhua Village	Liuqiao Village
Coal used per family (kg/Family)	256(27.6%)	234(31%)	296(37.1%)
Straw used per family (kg/family)	705(51.1%)	456(37%)	410(36%)
Firewood used per family (kg/family)	85(6.2%)	57(8%)	60(5.3%)
Liquefied petroleum gas used per family (kg/family)	46.5(11.6%)	60(19%)	57(17.1%)
Electricity used for illumination per family (kWh/family year)	194(3.5%)	208(5%)	210(4.5%)
Total energy consumption (kg Standard coal/family year)	689.2(100%)	531.7(100%)	569.9(100%)

Notes: electricity is treated as 860 kcal equivalent to each kWh

**Table 4.17 Energy price for farmers investigated**

(yuan/kg, yuan/kWh)

	Coal	Straw	Firewood	Liquefied petroleum gas	Electricity
Price	0.35-0.4	0.14-0.2	0.25	3.5	1.4-1.5

Table 4.16 and Table 4.17 show separately the living energy consumption by farmers investigated and the local energy price. The result shows that the ratio of straw and firewood is still 40-60% the total living energy consumption, and the coal is about 30-40%, and the liquefied petroleum gas is only 10-20%. The main reason is that the price of liquefied petroleum gas and other high quality energy is too high. Calculated according to calorific capacity, if the price of straw is 1, then the price of firewood is 1.5, and the price of coal is 1.5-2, and the price of liquefied petroleum gas is 5-7, while the price of electricity is even much higher. So according to the present economic condition, the consumption of liquefied petroleum gas is a try, the electricity consumption is much less.

#### 4.3.3 Market potential and analysis of intensified gas supply with straw gasification technology

According to the investigation, the intention for farmers to use cooking energy from now on is shown as Table 4.18. The result shows that: 100% farmers think that they would not use biomass energy and coal as cooking fuels under the better economic condition; 70-80% farmers will use electric cooking facilities at the same time. More than 85% farmers agree the intensified gas supply with straw gasification technology and are willing to use it, because it is cleaner and more convenient to pipe gas to user family. So the market potential is large according to the demand., and major of the villages can set up such projects. Analyze from perspective of

resource, except minor farmers who grow vegetables, major farmers have enough straw for gasification. Thus the market of intensified gas supply with straw gasification technology will be decided by investment and gas price.

**Table 4.18 Cooking energy intention for farmers investigated**

Cooking Energy Types	Future Cooking Energy Intentions of Farmers		
	Tangwan Village	Xinhua Village	Liugiao Village
Coal	0	0	0
Traditional Biomass Fuels	0	0	0
Liquefied Gas	60%	56%	70%
Biomass Gas	70%	65%	59%
Electricity	80%	73%	70%

The gas made with crops straw produces less heat than normal gas, so it is not adaptable to far distance convey. Normally one station each village. Most villages have several hundred families and the gas station is usually not very large. But the investment in station and the gas price per cubic meter is high, so the risk of investment in gas station is large. Therefore the ownership of gas station should be collective investment and collective ownership, the investment should be raised by farmers at the village and special technicians should be employed to operate and manage the work, to convey the gas to each family and charge according to the quantities used. The profit can be used for maintenance and facilities renovation.

The investigation also asked the farmers the intention to raise money to set up a gas station, the result showed that 30-40% farmers are willing to invest 2,000-3,000 yuan, and 40-50% farmers are willing invest 1,000-2,000 yuan, and 30% farmers are willing invest 500-1,000 yuan, only 10% farmers will invest less than 500 yuan. The data show that the market potential of intensified gas supply with straw gasification technology is very large when the average income of farmers reaches some degree.

#### **4.4 Market Potential and Analysis of Refuse Landfill Power Generation Technology**

##### **4.4.1 Status of refuse disposal in China cities**

With the development of national economy and urban construction, the urban residential refuse is increased annually. The recent quantities of urban residential refuse are show as Table 4.19.

**Table 4.19 Urban residential refuse from cities in China**

Year	Residential Refuse Cleared (10 thousand tons)	Year	Residential Refuse Cleared (10 thousand tons)
1979	2,508.0	1988	5,751.3
1980	3,132.0	1989	6,291.4
1981	2,606.0	1990	6,766.8
1982	3,125.3	1991	7,636.0
1983	3,452.0	1992	8,262.0
1984	3,757.4	1993	8,791.0
1985	4,477.3	1994	9,952.0
1986	5,008.7	1995	10,748.0
1987	5,397.7	1996	10,825.0

Data source: *Chinese Statistical Yearbook*, 1997.

The table above shows that the output of urban residential refuse is very large, and is increasing with a ratio of 10% annually. It is estimated that in 2000, the urban residential refuse will reach 150 million tons.

#### 4.4.2 The urban residential refuse composition in China

With the growth of national economy and the improvement of civil living condition, the composition of urban residential refuse varies continuously, and the tendency is: inorganic ingredients decrease annually, and the combustible ingredients and the heat value increase annually. Paper, plastics, metal, glass, and other recoverable waste which account for 20% total urban residential refuse. But the cooking refuse is the major part, and the characteristic is low heat-value and high water ratio are (shown as Table 4.20)

**Table 4.20 Comparison the urban refuse composition between other countryies and Shanghai, Shenzhen, Taiwan (%)**

	U. S. A.	Japan	Germany	UK	France	Shanghai	Shenzhen	Taiwan
Cooking Refuse	17.0	18.6	16	18	15	79.1	60	26.5
Plastics, Rubber, Leather	6	12.7	4	1.5	4	5.69	14	13.6
Paper, Bamboo and Wood	44	46.2	31	33	34	7.57	11	26
Fabric	2	16.4	2	3.5	3	1.65	3.6	12.6
Glass, Metal	20	16.4	18	15	13	4.34	5	21.6
Ash, Spall and Shingle	11	6.1	22	19	22	1.51	6.4	21.6
Ratio of Inflammable Matter	52	60	37	38	41	-	28	52
Ratio of Organic Matter	68	65	53	56	66	-	88	78.4

Data source: *Municipal Waste Treatment and Disposal*, China Building Industry Press, 1992.

The difference in urban refuse composition among cities in China is great and unlike the foreign condition. Generally speaking, the ration of inorganic matter is high and the heat-value refuse is high in the north of China, while the ration of organic matter is high and the ration of water in urban refuse is high in the south cities.

#### 4.4.3 The market potential and analysis of disposal technology for urban residential refuse

At the present time, the urban residential refuse in China is increasing 10% annually, according to the prediction from relative department, when it is 2000, the urban residential refuse in China will 150 million tons, and 20% are innocent treatment rate. The daily treatment will reach 540,000 tons in 2000. The processing capacity increased is mainly composed of sanitary landfill, so the market potential in this industry will be attractive.

According to the investigation and collection data of 143 large and medium cities from China Urban and Rural Construction Department, at the present time there are 394.8 million tons of refuse, while the daily treatment in only 336,000 tons, and the total treatment one year in only 123 million tons which account for about 3% the total (shows as Table 4.21). At the same time, more than 100 million tons of refuse produced every year. The present condition shows that the task of refuse disposal is very difficult.

**Table 4.21 Storage of urban residential refuse from 143 main cities in China and the chief handling way (by the end of 1996)**

<b>1. Refuse Stack</b>	
Storage (thousand ton)	3,948,274.5
floor space of stack (thousand m <sup>2</sup> )	4,805,322.0
Stack sites	1,455
<b>2. High Temperature Compost Treatment Plants</b>	
Numbers	186
Treatment Capacity (tons/day)	36,585.6
Project Investment ( thousand Yuan)	249148
<b>3. Sanitary Landfill Plants</b>	
Numbers	600
Treatment Capacity (tons/day)	289,831.34
Total Design Capacity of Landfill (thousand tons)	1,096,943.4
Total Project Investment (thousand Yuan)	1,463,478.1
Liquid Penetration Treatment (ton/day)	18,497.43
<b>4. Landfill at Suburbs and Simple Treatment</b>	
Numbers	77
Treatment Capacity (ton/day)	9,935.55
Project Investment (thousand Yuan)	383,806

At the present time landfill is the main way of refuse treatment, its capacity is 6.2 times of the total of other ways. According to the planning to 143 large and medium cities by Construction Ministry, sanitary landfill plants will be set up with a great quantity. By year 2000 the numbers will reach 239 and the daily treatment capacity will be 140,000 tons, and the design capacity can be over 7.1 billion tons, which will make a wide market for landfill power generation, the data shown as Table 4.22.

**Table 4.22 Plans of setting up landfill plants for 143 cities from 1997 to 2010 in China**

	Numbers	Treatment Capacity (ton/day)	Design Landfill Capacity (1,000 tons)	Investment Estimated (1,000 Yuan)
1997-2000	120	69,656	6,454,621	2,593,400
2001-2010	119	74,997	717,192	3,186,132
Total	239	144,653	7,171,813	5,779,532

## **CHAPTER 5 Main Countermeasures for Overcoming the Barriers in Commercialization Process**

### **5.1 Countermeasures Now Available Domestically and Internationally**

Many countries including China have taken some measures to support the development of renewable energy and made various supportive policies and accumulated a lot of experiences, which can be shown as following:

#### **5.1.1 Enhance legislation to protect the development of renewable energy**

To Make law and regulations or statutes can establish the status of renewable energy with laws, and protect the development of renewable energy. Many countries take this way, and facts proved that it is necessary. For example, the main reason of the well-known wind power generation and the biomass energy power generation in Denmark is that the government support and protect the renewable energy technology with law tools. In 1976, the Electricity Power Law stipulated that all public utilities (power plant, heating plant, etc.) must take biomass energy as alternative fuels, and require them to buy electricity with preferential price from biomass energy or wind energy or other renewable energy power plant. At the present time, the renewable energy availability in Denmark is concentrated on forestry refuse, straw, urban refuse and other biomass energy and wind energy. Biomass energy and refuse account for 93% energy value and wind energy accounts for 7%. In 1995, all the biomass energy and refuse utilized were equivalent to 1.8 Mtoe. In order to encourage heating plant and electricity plant to use biomass fuels, Denmark government issued 3 regulations to encourage abatement of CO<sub>2</sub>: "*Government Subsidy for Biomass Fuels Utilization and Setting up Pyroelectric Power Plant Law*", "*Power Generation Subsidy Law*" and "*Government Subsidy Accomplishment Local Area Heating Supply Net Law*". These laws not only accelerate the development of biomass energy technology, but also protect the benefits of plants that utilize biomass fuels.

Countries like the USA, Germany, the UK, Austria all issued Electricity Power Laws, which definitely regulate that the electric power company must allow electricity power with wind power, water power or biomass energy technology to incorporate in electric network and buy the electric power with special price. For example, the

"*Utilities Management Policies Act*" and "*Federal Electric Power Law*" by USA government in 1978 specify that the public electric power companies can buy electric power with "avoidable cost" from qualified renewable energy power plant (scale less than 80MW).

The first electric power law in China was enacted in 1995. the law clearly and definitely encourages using solar energy, wind energy, geothermal energy and other renewable energies. At the same time, the Electric Power Ministry specially made "*Wind Power Incorporating in Power Network Regulation*", which definitely stipulate: electric grid much buy electricity generated by wind power plant nearby, and the electrovalence should be decided by the principle of repaying capital and interest plus reasonable profits, the part over average electrovalence should be shared by power company and users. Fact shows that this is an effective way, but the drawback is that it doesn't explain whether the regulation is suitable for biomass power generation system. In 1997, the "*Saving Energy Law*" was issued officially and established firmly the important position of new energy and renewable energy in whole energy system.

#### **5.1.2 Make program, and definite development goal**

It is another general international way to push forward the development of biomass energy and other renewable energy. According to the foreign experiences, the goal of the program is very important, and it should be positioned a high starting point and be encouraging and challenging. Table 5.1 shows the prediction for American biomass energy development. The data fully display the ambition to develop renewable energy. Many other countries also made ambitious programs. For example, Denmark began renewable energy program in middle of 1970s, and in the "2000 energy program" made in 1990, it is require that the power supplied by renewable energy double and biomass energy is the major. On the basis of the program, Denmark made a series of development projects for renewable energy, such as "1991-1995 central biogas project", etc. theses measures greatly accelerate the development and utilization of biomass energy. Now 1.4% energy demand is provided by straw in Denmark. Up to now, more than 60 power plants burning straw (mainly wheat straw) run in Denmark, and many have set up heating systems and power systems for towns and villages, and have got pretty good results, even the small scale power plant such as 2,000kW (can supply 200 families) can make profits.

**Table 5.1 2005-2015 prediction and goal of power generation with biomass energy in U. S. A. (fundamental program)**

Technology type	Year 1995 (actual)	Year 2005	Year 2010	Year 2015
Refuse power generation(GW)	2.43	3.34	3.89	4.19
Wood and other biomass power generation(GW)	1.86	2.00	2.21	3.92
Wind power generation(GW)	1.83	2.97	3.78	5.39
Photovoltaic power generation(GW)	0.01	0.08	0.19	0.35
Geothermal power generation(GW)	2.97	3.04	3.19	3.46

Data source: DOE/ETA, *Annual Energy Outlook*, 1997.

In march, 1993, the UK declared that the renewable energy power generation will reach 1,500 MW by 2000, and biomass energy power generation and refuse power generation are the major parts. Besides the countries above, other EU countries also made national biomass energy development program, for example, Austria planed to achieve 20% primary energy sources with biomass energy in 2000.

The facts shows that a scientific development program can encourage and accelerate the technology development. For example, there are more than 69 million tons TOE (ton oil equivalent) renewable energy in 14 EU countries by 1993, which was about 5.3% primary energy consumption (1.326 million TOE) by EU the same period, and over 40 million TOE were biomass energy, which accounted for 58% total energy exploitation.

The China government has given great concerns to the development of biomass energy and other renewable energies. Especially from 1980s, renewable energy has been listed in "*China's Agenda 21*" and "*9th 5-year National Economy Development Program and Long-range Planning Target Outline*" as an important strategy. In 1995, the former State Planning Commission, SSTC and SETC made together "1996-2010 new and renewable energy development outline", which was confirmed by leaders of the State Council. There is no doubt that these measures will accelerate the growth of renewable energy. According to the target of the outline, the major task of biomass energy in next 15 years is: firewood forest areas in 2000 and 2010 should be 5.4 million hectares and 13.4 million hectares; to realize commercialization manufacture and sale for saving firewood cooking utilities; to develop the high level application ability of biomass energy, and the families which use biomass gas in 2000 and 2010 should be 7.55 million and 12.35 million in China, and the gas be 2.26 billion m<sup>3</sup> and 4 billion m<sup>3</sup>; biomass energy power generation installed capacity will be 50,000 kW and 30,000 kW in 2000 and 2010. Obviously,

these targets will make a new step for the development of biomass energy in China

### 5.1.3 Make encouraging economy policies

It is a key step to achieve the goal of the outline for government to take encouraging finance and banking measures, and it is an important policy to accelerate the commercialization of biomass energy and improve the market permeability and economic competitive ability, especially in the beginning of the commercialization, because of the difference between the ability-to-pay for new technology and the duplicate target by government, support by government usually become the key factors in market growth.

#### (1) *Investment subsidy.*

It is the most common financial way. Here is an example of Austria. Austria is a country which has rich forest resource. In order to decrease the environment pollution from agriculture and woods waste and to promote the development of biomass energy, the Austria government decided early to give subsidy to biomass energy heating and generation users and suppliers on the basis of actual need during the development of biomass energy. For example, a subsidy equivalent to 5% investment will be granted to private heating station; 35% investment subsidy is offered to heating station owned by public utilities and agricultural cooperative; a subsidy equivalent to 30% cost of thermal converter is offered to users. Facts show that these measures are actually encouraging and stimulating, and get notable result, shows as section 1. Table 5.2 shows the basic condition of investment composition for over 40 heating station with biomass energy. The data indicate that Austria government has important effects on the development of biomass energy.

**Table 5.2 The investment composition of heating station with biomass energy in Austria**

Investment type	Proportion (%)
Private investment	14
Relative cost input	21
Loan	2
Government subsidy	24
Loan with discount	39
Total	100

Data source: *The Diffusion of Biomass District Heating in Austria*, Institute of Technology Assessment of Austrian Academy of Sciences, April 1995.

In China, much attention is paid to biomass energy. From central government to local government all issued a series of subsidy policies to support the development of biomass energy. First of all, central government arrange research and development projects relative to biomass energy in each "5-year" plan and invest lots of money; second, central and local government invest a lot in experimental demonstration project for biomass gasification, direct burning, and liquidation and carbonization, and accelerate the development of biomass energy technology; third, some county level government also issue preferential economic policies to promote the investors' enthusiasm and accelerate the biomass technology commercialization process. For example, the government of Xinbin County, Liaoning Province, decided: any farmer who set up "four in one" ecological mode (biogas project as major, combined with solar energy, livestock breeding and planting), will get the subsidy of 500 Yuan from county government and 100 Yuan separately from township and village, which will also supply a loan of 2,000 Yuan with low interest. Each high efficiency saving firewood cooking stove can get 50 Yuan county subsidy and 50 Yuan subsidy separately from township and village. Some counties also provide technology subsidy for farmers who spread biogas technology, in addition to increasing house area and preferential cement price.

## **(2) *Preferential price.***

To make preferential price for electricity incorporating in electric network can have great effects on renewable energy power generation during its commercialization process. In many countries such as the UK and Holland, electric companies make so low electricity price by means of their monopolizing position that development of renewable energy power generation technology is jeopardized. Many developed countries have made favorable price for renewable energy power generation from 1980s, they ask electric companies to provide subsidy for price of electricity incorporating in power network or purchase the electricity from renewable energy with avoidable cost.

In Denmark, according to the "*Electric Power Law*", electric companies must pay 0.55 Krone/kWh to purchase the electric power from biogas and other biomass energy power plants, while the normal sale price for electricity from biomass energy plant is the conventional price, namely about 0.35 Krone/kWh.

In UK, according to the regulation of "non-fossil fuels obligation (NFFO)", the price of electricity incorporating in power network from biomass energy and refuse power generation plant is the average price of electricity market. (2.5 penny/kWh in UK power network in 1996), the price difference (as the contract price for biomass

energy power plant is 3.2 pennies to 5.79 pennies/kWh) supported by government, and came from the part charging for what hike electricity price.

**(3) *Preferential tax.***

On the basis of their tax systems, many countries provide tax abatement or exempt for investment in biomass energy and other renewable energies devices, for users buying the relative products. In USA, according to *Energy Policy Law* issued in 1992, the tax abatement in investment in solar energy or geothermal projects can be up to 10%, and 1.5 cent/kWh subsidy is given to the wind power generation and biomass power generation devices running before June, 1st, 1999, the term of validity is 10 years since the investment begins. The criteria was made according to the commodity price at that time, and the present ratio has increased to 1.65 cent/kWh.

In Japan, the *Energy Supply and Demand Construction Reform and Promote Investment Tax Law* issued in 1994 describes that new power generation equipment with wind energy, solar energy and refuse can be given a tax abatement of 7%, and the reduction should be less than 20% tax; or a depreciation equivalent to 30% purchase fees in the first year after its running. Either can be chosen.

In china, now a 5-year tax exemption policy for bagasse power generation and biogas power generation is available. But the suitability is still unknown to other biomass energy.

**(4) *Low interest loan and credit guarantee.***

It is a simulating means in many countries, too. For example, in order to encourage the private enterprises to develop biomass energy and geothermal utilization (power generation and heating), the USA Energy Ministry provides guarantee for loans: 240 million dollars are supplied for alcohol-making from biomass, and 500 million dollars are supplied for geothermal projects.

In China, the government set up special fund for rural energy in 1992, which is mainly used to pay interest for loans for large and medium biogas projects, solar energy utilization and wind power generation technology. Although the loans is not much, only 120 million Yuan, but the discount is up to 50%, so it can take great effects on the development of renewable energy technology.

**(5) *Set up risk investment fund.***

On the basis of their finance systems, various measures are taken in different

countries. In USA, the creative investment system provides a new market for renewable energy technology. For example, risk investment results in a quick development of wind power generation. Some corporations establish 10 years special funds for solar energy equipment to residence. In Indonesia, the World Bank and Global Environment Fund (GEF) provide money to set up rolling forward fund, which can enhance the support for distributor to spread photovoltaic system, and popularizing the development of solar energy photovoltaic system.

**(6) *Implement the charge system of paying by polluter.***

This policy is direct against the urban refuse disposal and excrement of livestock and fowl.

#### **5.1.4 Create new operation system**

Now the low efficiency and high cost of renewable energy technology are the major barriers for its commercialization, and biomass energy technology is the same. so it becomes the social focus to promote the conversion efficiency of renewable energy technology and reduce the cost, many governments and the scientific circles have taken indefatigable efforts and numerous research in finance system and scientific research. The British experiences proved that a scientific operation system suitable for national economic system can make great progress in technology of biomass energy and other renewable energies, and accelerate its commercialization process. UK began NFFO in 1990 whose nature can be summarized as a system combining fair competition and raising power rate. Its characteristic is not the same as those of other countries, which directly give subsidy or tax reduction for renewable energy technology and business, it is the open bidding and fair competition that improves the technology level and reduce the cost, and the subsidy must be confirmed clearly its level and quantities. the basic operation steps are shown as following :

- (1) The government makes development plan and target for renewable energy power generation, and decompose them, such as one period with 5 years, and decides the type and goal of each step ;
- (2) To invite bids or tenders throughout the world according to the phase goal;
- (3) The renewable energy corporations (such as biogas power plant, wind power plant, etc.) hand in a bid freely, submit a tender (report) and initial electrovalence in power network. In order to be chosen., they have to try their best to take advanced technology and reduce the cost, and thus accelerate the growth of renewable energy technology.
- (4) An intermediate agency evaluates the tenders in technology, economy and other aspects on the basis of national electric power law and other relative regulations.

- That's what is called "safety guarantee" test ;
- (5) The power corporations which pass the primary estimation work out and submit the last tenders, and confirm the final electrovalence.
  - (6) Government plots the power purchase cost curve (shown as Figure 5.1) with the final scale and price submitted by renewable energy power corporations, and makes different subsidy with different installed capacity.
  - (7) Government confirms the result the which power corporations are chosen to incorporate in power network and its development scale and electrovalence according to the reserved target, as well as the final tender price and sign contracts.
  - (8) To implement the contracts and provide subsidy for these corporations. Because the present average price of electricity is relatively low, namely 4.0 penny/kWh, and the electrovalence from renewable energy power plant is high (for example, the electrovalence is up to 5.79 penny/kWh for gasification with waste of agriculture and forest, shown as Table 5.3), the difference will be counteracted by hiking up electrovalence for these corporations.

The facts show that this method can fully mobilize the bidders' activities, because even under a condition of high renewable energy cost, the bidding corporations can make profits according to the market operation system. What's more, it can notably improve the renewable energy technology, and reduce the power cost. UK began this method from 1990 and had 4 round tenders till 1997. From the 1st round to 4th round, the cost of power with renewable energy technology (such as landfill biogas power generation) reduced half and reached 3.2 penny/kWh, shown as Table 5.3 and Figure 5.1.

**Table 5.3 The highest contract price of electricity generated by renewable energy**

Technology type	The highest contract price paid (penny/kWh)			
	Year 1990	Year 1991	Year 1994	Year 1997
Wind power generation	10.0	11.0	4.8(>1.6MW)* 5.9(<1.6MW)	3.8(>1.6MW) 4.95(<1.6MW)
Small scale water power generation	7.5	6.0	4.85	4.4
Landfill gasification power generation	6.4	5.7	4.0	3.2
Power generation by burning urban and industrial refuse	6.0	6.55	4.0	3.4(FBC)** 2.8(CHP) ***
power generation by gasification of energy plants and waste of agriculture and forest	-	-	8.75	5.79

Notes : \* wind power plant with scale over 1.6 MW

\*\* FBC fluid-bed combustion technology

\*\*\* CHP combination heating produce technology

Figure 5.1 Supply curves for NFFO4 technology bands

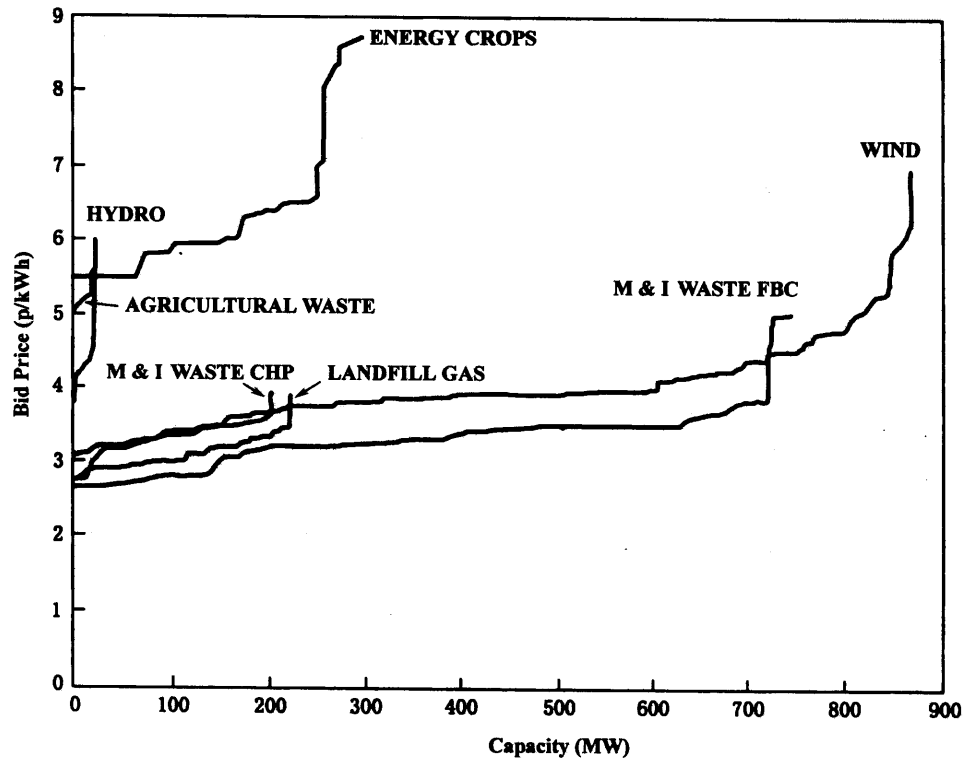
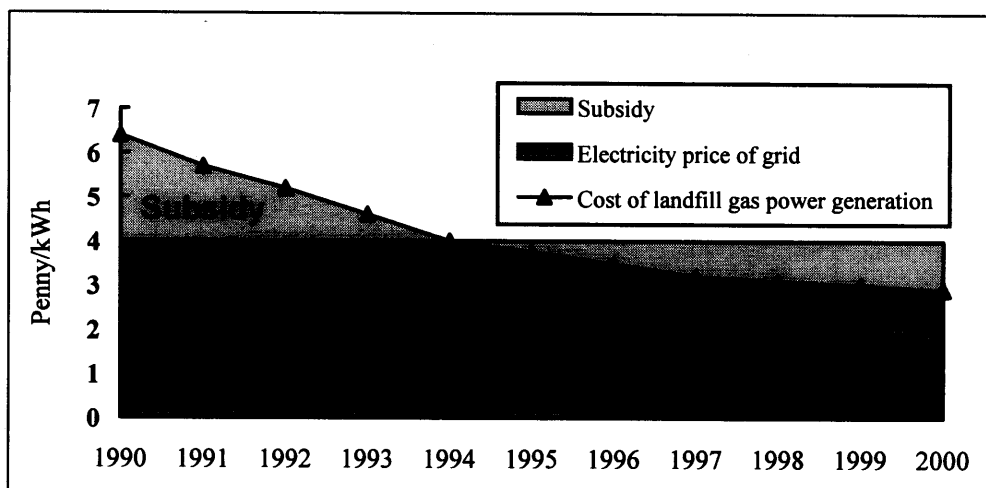


Figure 5.2 Cost and subsidy for power generated by renewable energy in different NFFO phases in UK



Specially, this system is favorable to form the market of renewable energy technology, now the corporations which are invited to bids and submit tenders for renewable energy development projects become more and more, the competition also becomes intense, and the project scale is becoming larger. The total capacity brought up by application forms in the first round in 1991 was 1,400 MW, and the actual contract capacity was 153 MW; but in 1997, when the 4th round tender, the total tender capacity reached 9,400 MW, and 890 applicants. 426 projects passed the " safety guarantee " test and the capacity is 2,552 MW, the final number of projects were confirmed was 195 and the total contract capacity is 842 MW.

Third, as the cost of power by renewable energy decreases continuously, the subsidy reduces continuously, too. It is estimated that the subsidy can be cancelled completely in 2000, and can diminish the governmental finance burden greatly.

The facts above shows that the final target of NFFO - to set up a basic renewable energy market - is becoming reality gradually. In the future, even without governmental subsidy, the renewable energy power generation technology can compete with normal power generation technology, and become an important factor to improve the economy and society development.

Recently, with the changes of economic systems in China, some operation systems based on market economy are entering the renewable energy projects. For example, during the establishment process of biogas clarifying-tank at Yiwu County, Zhejiang Province, competitive system were introduced, inviting public bids and tenders and competing fairly made the project develop quickly with high quality, and got notable profits.

#### **5.1.5 Establish technology guarantee and service system**

##### **(1) *Resource investigation and estimation***

It is a prerequisite for the development of biomass energy and other renewable energies. Some countries, especially developed countries, have investigated and estimated the geothermal energy, wind energy and solar energy, etc. They established databases and provided data for designing and addressing non-government projects. The resource exploration and estimation in USA reaches a rather high level. They analyze and estimate with advanced GIS technology in renewable energies including biomass energy, and classifies 3 grades: total resource capacity, available capacity and economical available capacity. It not only explains in detail the development potential of renewable energies, but also clarifies the

development qualification. So it is a necessary step for design and estimation of projects, prediction and plan for resources.

**(2) *Make technology standard specification***

Most countries regulate the efficiency, reliability standard, specifications and test steps for solar energy and wind energy equipment, passive solar house biomass power generation equipment. The technology standard and specifications and reliability test are very important in protecting the users' trust to new products and new technology. Such foundation in China is weak, especially for the biomass energy project.

**(3) *Information, propaganda and training***

There is a close relationship between the development of biomass energy and the custom of public consumption, while the biomass energy applications will affect the public consumption customs. The practices show that any successful policy must be carried out based on the related propagation which tell people how to do it. So it is necessary to coordinate propagation and education programs for developing biomass energy applications.

To customers, information and propagation can enhance the public understanding and trust in renewable energy technology, can promote the commercialization of new energy technology. To producers and salesman, information and propagation is the important way to expand market and sales volume, but also promote technique, improve technology quality. Especially in the beginning of commercialization of new energy technology when its performance, reliability and life-span have many problems and many of them are caused by unsuitable installation and use or maintenance. So it is very important to establish an information and education system.

Many developed countries made great efforts in these ways. The information system includes public propagation, namely publishing and distributing guides and pamphlet, holding exhibition and workshop, and providing special information for technicians, etc. They have set up information databases oriented to various objects (users, technicians and manufacturers).

**5.1.6 Set up special department**

In order to enhance the management, coordination and support for renewable energy technology, the central government in many countries establish a special department,

such as Environment and Energy Ministry in Denmark, Research and Technology Ministry in Germany, Economy and Business Ministry in Netherlands, Energy Ministry in USA, Industry and Business Ministry in UK, Renewable Energy Ministry in India, etc. They are no doubt the authoritative leaders and coordination departments for renewable energy. Facts show that their existence is very important for the development of renewable energy in these countries, especially in India. For a long time, resource waste, energy shortage and lack of electric power make many difficulties in India. Today there is a power shortage of 14%, and over 28% during the peakload period in India, and 41% rural areas have no electric power to use. So, to develop biomass energy, solar energy and wind energy and other renewable energy, in addition to the ordinary energy, is a wise choice. India government established Renewable Energy Ministry responsible for the management of renewable energy. Now in this developing country, the installed capacity of wind power generation reached 850 MW in few years which greatly exceeds that of China and approach Denmark, only next to USA and Germany; India made well-known progress in solar energy photovoltaic system and application and development of biomass energy.

## **5.2 Feasibility Analysis on Countermeasures Now Available Domestically and Internationally**

In last section, some countermeasures are introduced, which have been adopted by some countries to overcome a variety of barriers encountered in the course of the commercial development of some renewable resources such as biomass energy.

Although they are not very systematic and complete, their contents have come down to all of the main respects of the course of commercialization. From the view of their property and function, they can be classified into four categories, they are:

- Compulsory measures: to enact law, statute or ordinance.
- Incentive economic policies: to implement subsidies and preferential price or derated revenue, to provide a loan of low interest
- Innovating method: to invite public bidding, adopt impartial competition or set up scrolling fund
- To create a guarantee and service system: to constitute technical norm, to set up information systems and information databases, survey and assess resource.

Now, we will discuss the above types one by one except the fourth which is familiar to us because of its lucid relation with technical commercialization.

### 5.2.1 Incentive economic policies

#### (1) *Subsidy policy.*

Subsidy policy has manifold formats. The first is subsidy for research and development, namely the subsidy provided for scientific research institution; the second is the subsidy for investment, namely the subsidy provided for investors; the third is the subsidy for output, namely the subsidy provided for production; the fourth is the subsidy for consumers. In addition, in foreign countries there also are examples that subsidy is likewise provided for bagmen or salesmen. It has been instantiated that utilizing different type of subsidy to diverse objects can take distinct effects and gain different ends. The first can conduce to research and develop new technique; the second helps to elevate the positivity of the investors and then improve productivity and enlarge the scale of production; the third lends itself to augment the output and the economy benefits of corporation; the fourth and the last subsidy can encourage consumption and in turn accelerate the development of renewable resources. But which subsidy should be adopted depends mainly on the mature degree of technique, the development phase of commercialization and the circumstance of politics and economy.

Summarily, the Chinese subsidy policies on biomass energy technique are mainly consist of the following aspects:

- To provide career fees and all or part of the research expenses for scientific institutions of all levels, which undertake the research and development of the biomass energy technique.
- To provide funds for national or local important research programs. It is shown statistically that the fund, which was used in this kind of items in the period of "Nine Five", exceeds one hundred million Yuan.
- To provide funds for important scientific and technical exemplary items and training. For example, in the *"project of the energy comprehensive construction in one hundred counties in China"*, the ministry of finance appropriated 6 million Yuan for the work of scientific and technical exemplary items and training of rural energy, of which biomass energy is the main part.
- Some local government provide subsidy for spreading the technique of biomass energy.

The implement of subsidy policies, which leads to the popularization of high efficiency kitchen in 80 percent of the rural families and render the total number of biogas ponds used in the country over 600 million and the number of domestic husbandry large-sized or medium-sized biogas projects over 600, results in the

progress of the technique of biomass energy and enlarge the application scale and facilitate the development of rural economy and the amelioration of the agriculture ecology circumstance.

The overseas subsidy can be classified into the following three categories:

Firstly, giant fund is offered to the study and development of the technique of renewable energy such as biomass energy and to experimental unit and paradigm. It is shown statistically that the fund provided by the national governments of OECD for the study and development of the technique of renewable resources during the years from 1977 to 1985 amounted to 7000 million dollars, 650 million dollars in 1996, and U.S.A. accounted for 270 million dollars among them.

**Table 5.4 R&D fee for new energy resource and renewable energy resource offered by IEA national government in 1996**

unit: million dollar

	IEA sum	The U.S	Japanese
Solar energy	354.16	148.67	74.48
Wind energy	99.19	31.42	5.58
Ocean energy	2.62	-	1.35
Biomass energy	114.51	53.20	5.45
Geothermal energy	70.06	29.40	34.95
Hydropower	8.75	3.48	-
Total	655.30	271.97	121.81

Source: *Energy Policies of IEA Countries 1997 Review*, OECD, May 1997.

Secondly, capital subsidy is provided for the commercialization of the renewable energy resource technology, as some countries including Austria do.

Thirdly, subsidy is also provided for output. The direct capital subsidy method, which is independent of the operation condition of enterprises, can not be so much incentive as it has been expected, a new type of subsidy, that is, provided for products according to the production state of the enterprise of renewable energy resources and its output, is now being adopted by many foreign governments. For example, favorable electricity price for the power plant using biomass energy in countries such as Denmark and England advertised formerly. But there is yet no such incentive policy in China. The merit of the policies of production subsidy is to engender affinity between subsidy and the enterprise of renewable energy, which has direct influences on the production cost price and meanwhile encourage enterprises

to try to augment their total output and reduce its production cost. The defect of this type of subsidy is the source of fund for subsidy, which should be raised by the government. Once it become difficult to raise money, the policy has to be suspended. However, it is known to all of us that the Chinese finance is intense and a good many enterprises need support from the government and need a great deal of fund. Some foreign countries disburse this fund by the tax of carbon (e.g. Denmark) or the tax of fossil fuel, which can not be taken into effects in China. If this fund is assumed by the electricity network, it will be restricted by the payoff state of the electricity network; if this fund is proportion by users, it is dependent on the number of the users and how much they can bear. So it should be investigated and analyzed materially.

### **(2) *Tax policy.***

There are two kinds of tax policies of different property. The one is preferential tax policies, such as derated tariff, derated estate-forming tax, derated sale tax, derating value-added tax, derated income tax and so on. Theoretically speaking, derated tax need not subsidy of a great deal of fund from the government, but cut down a part of the revenue of the central government or local governments, and the enterprises of biomass energy are all small-sized, so it is easy to carry out. However, because most types of taxes except tariff are not reckoned in production cost and only affect the production price, they have no direct influences on encouraging enterprises to improve their manufacture technique ,heighten the efficiency and reduce the cost.

The other is compulsory tax policy, such as having the ones who produce the pollutant of junk and fowl dung and so on pay the prescribed fee. The practice shows that such policies especially charge policies of high standard and high intensity are not only favorable to develop and make use of biomass energy but also facilitate to improve technique and promote the level of technology. Therefor, such policies have indispensable important incentive action.

### **(3) *Price policy.***

The cost of renewable energy resource production is generally higher than that of general energy resource production, so most countries adopt favorable price policy for renewable energy resource. For example, in the respect of biomass energy some countries such as England and Denmark provide subsidy for the price of electricity produced by biomass energy to encourage the development of technology of using biomass energy to produce electricity. In China some favorable policies on the aspect have also been enacted. For example, high price policy which is prescribed to be 1.20Yuan per m<sup>3</sup> is adopted in Shanghai for some central large-medium biogas

supply, and much more local governments adopt welfare price for landfill gas and biogas, which is only half of the practical cost or lower. In fact, the former policy, that is, high price policy, helps to strengthen the enterprise management, boost efficiency and stimulate the positivity to develop biomass energy, but it is only suitable for the areas having high economic endurance ability; the latter, namely welfare price policy, not only makes against the progress of technology but also can not promote the investor's positivity, and so is not worth advocating.

**(4) *Low-interest loan.***

It can reduce the interest in the course of repayment of capital and conduce to reduce cost. German, Austria and China all adopt this policy.

The merit of such policy is obvious, however its defect is also very salient, that is to say, it requires that the government raise a great deal of funds, otherwise this policy can not continue.

**5.2.2 Compulsory countermeasure**

From the practice of the countries, it can be seen that incentive policy is not omnipotent and its application need some conditions, among which some administrative and legal restriction measures are the most important. For instance, in some countries it is prescribed in electric power law relative to using renewable energy resources to generate electricity, that public power companies must purchase with special price the electricity power that is generated from renewable energy resources nearby. It is not casual to put forward such provisions, it has profound technical and economic reasons. In general, the power plants using renewable energy resources (including the biomass energy power generations) are small scale scale and their running stability and economy are inferior to that of general energy resource power plants. Because the renewable energy resource power plants need to sale their surplus electricity power to electricity power companies and need power supply from electricity power companies when not autarkic, and because they can not assure stable power supply to the electricity network at the period of apex of consuming electricity power, electricity power companies should take into account the problem of capacity when they are calculating the electricity price, which will on the other side influences the cost of the renewable energy resource power plants. In such case, without compulsory prescribed electricity price these disperse small power plants are difficult to incorporate into the electricity network and enter the market of electricity power supply and marketing. Therefore, when enacting incentive policy, it is necessary to take into account certain relevant restrictive

policies and measures at the same time.

### **5.2.3 Innovation mechanism**

Two types of innovation mechanism have been mentioned above, among which one is to create special fund and rolling development mechanism. This mechanism has been successfully applied in the generalization of the photovoltaic electricity generation technique in Indonesia and procured excellent effects. In China there are some similar practices in the development process of the technology of rural energy resources and biomass energy including the photovoltaic electricity generation technique, e.g. in Shanghai. The Shanghai municipality has ever appropriated a fund of 10 million Yuan to the office of Shanghai rural energy resource as a special fund and made the rolling development according to the rules of market economy, and has also obtained positive results. It has been proved by practice that without added investment such measures can however extend the domain of the biomass energy technology, increase the opportunity of employment and accelerate the development of commercialization.

The another is to invite public bidding and adopt impartial competition mechanism. Such mechanism has been in function in England for years and acquired whole set experience. It proved a effective measure that could advance the commercialization development of renewable energy resource including biomass energy.

It need be complemented that to implement this mechanism requires the base of market mechanism and some other conditions, which mainly involve the following three:

The first one is public environment consciousness and the self-consciously performed obligation to protect environment, because the fund used to price difference subsidy should be assumed by users.

The second is to make certain by the form of law that electricity power companies must purchase the electricity power that is generated from renewable energy resources such as biomass energy.

The third is to need an authoritative administrative and harmonizing organization. It is conceivable that the NFFO could be implemented and successful without the organization and management of the Department of Trade and Industry of UK.

From above analysis, the following conclusion can be drawn:

- Both compulsory measures and incentive policies are need.
- Incentive policies have the irreplaceable promotion function.
- Important as incentive policies are, the market mechanism is also indispensable.

### **5.3 Policy Framework for Overcoming Barriers and Improving Commercialization Development**

#### **5.3.1 Creating a policy system integrated with both incentive and restrictive function**

Incentive policy is for the government to provide economic support, such as to distinctively provide fund subsidy, low-interest loan, derated tax and preferential price according to the practical demand and economic efficiency of the development of the biomass energy technology; restrictive policy include economic and non-economic kinds, for example, the formerly mentioned policy that impose fine on pollutant and forces contaminator belongs to restrictive policy; another is similar to such compulsory prescript as administration, law and statue that is applied in science and technology, for example, the management statue about the same electricity network, which was promulgated by the Chinese ministry of electricity power, belongs to juristic but not economic policy. It has been proved by practice that it is necessary to enact and implement such policy in order to advance the commercialization development of renewable energy resource including biomass energy.

In China the biomass energy technology has been greatly developed since the 1970' (especially 1990'), which is mainly attributed to the support of the government. However, from the perspective of the practical demand of the commercialization development, the support is not enough. The main reasons are:

- (1) The policy is not complete and methodical. For example, some supportive policies (to consult detail in the first and second section of the fifth chapter) were promulgated in course of generalization of the biogas technology in some areas, but such policies or prescript not only belonged to local ones but also limited to the biogas technology, that is, were not generalized to large-medium and middle-medium biogas projects, the straw gasification technology and the city rubbish burying technology.
- (2) Intensity of policies is not strong enough and they are not implemented rigidly.

Although the environment-protecting law has been enacted and the prescript of pollution fine also have been established in China, except for individual areas and domestic animal farms more than 80 percent of the domestic animal farms did not implement these policies and codes and furthermore the quantum of fine, which is generally from 1 to 3 Yuan per ton of dung sewage, is too low to have the effects of punishing and stimulating.

In disposing urban refuse, this prescript is only a formal and not executed conscientiously. In Haidian District, Beijing it has been prescribed that every family must hand in a cleanliness fee of 2 Yuan every month. The operation conditions shows that there is no money left after collecting and transporting refuse, and say nothing of disposing refuse.

- (3) The level is relatively lower, the type is too few and the effect is also limited. At the present time some policies have been enacted and promulgated to support constructing wind power plants and small-scale hydro power plants, however almost none has come on for developing biomass energy. The existing local policies are mainly to provide subsidy for users and their format is monotone, their effect is also limited; especially, they have no close relation with the goal of technique development. Because the support and help of policy can enlarge the scale of model, and further accelerate the advance of technology and the construction of commercial market with it, and make it a commercialized technique and at last gain the objective of increasing the proportion of biomass energy in the whole system of energy resources.

From the experience, to attain maximal effect of the government's supportive measures it is important to adopt relevant policies according to the different development phrases. For example, in the phrase of research and development the research institutions and relevant enterprises should be supported; in commercial model and the initial stages of entering market, some incentive policies for investors should be adopted; in the incomplete commercialization stages after the mature of the techniques, measures of encouraging users and investors should be adopted to accelerate the rate of infiltration of market and enterprises should be supported to develop international market.

At the present time, several main biomass energy techniques in China are in different stages :large-medium and middle-medium biogas project techniques have been mature gradually and can meet the demands of commercialization, so they should take some measures to create the foundation of market and improve the ability to

enter market. On the one hand, the execution of codes of environment-protecting fine should be strengthened, on the other hand some preferential measure in the aspect of loan, such as derating interest or allowance, should be provided for investors to make them feel profitable and positive to invest and take part in competition. The technology of disposing urban refuse, which has been mature and commercialized in foreign countries, was started comparatively later, it is indispensable to import some key equipment. Therefore, it is necessary to enact preferential policies on importation tariff and value-added tax together with increasing the pollution fine. The straw gasification technique is developing rapidly but more experiences of models are needed to improve the reliability and security, and so in the present stage the creation of special fund and rolling development are needed to enlarge the scale of production and exemplification.

Moreover, the innovation of social economy system in China also requires to create complete both incentive and restrictive policies. Now the Chinese economy system is experiencing intense transformation and the market economy system is expanding and forming. The market economy, which depends on the rule of value as the base and free competition as the motivity, has higher social economy efficiency than the planned economy system and is the effective measure to optimize the distribution of resources, but it has serious infirmity and fails sometimes, especially, almost incapable in disposition of the social justice and protecting the environment and even encumber their development. Thus it need intervention and modulation from the government ensure the sound development of the whole society. In the world there is no complete free market economy, which is meddled and controlled by governments to a certain extent. Such a system is what necessary for China. At present in China, the biomass energy technique, which is not satisfactory and profitable, can not enter market as a mature commercialized technique; but because of its universality, lustration and reproducibility, the biomass energy have far-reaching influence on improving the construct of Chinese energy resource system and decelerating and preventing the warning up of the global climate. In such case, it is necessary for the government in both positive and negative sides to enact policies and take some measures to help the biomass energy technology to overcome both technical and economic defects and realize its industrialization and commercialization.

### **5.3.2 Renovate notions, establish operation mechanism of inviting public bidding and competing fairly**

If that the policies is not complete and not executed rigidly is an important factor

that influence the commercialization development of the biomass energy technology, the conventionality and obsolete mechanism is a more important one that hampers its development. For a long time, the biomass energy technology, which is influenced by the idea of the planned economy system, along with the path of planned economy, partly or completely depended on the government's investment, running in the policy or welfare mode. Although it has made great progress and established a basement for the further development in study and development, models, generalization of application and so on. It has been proved by practice than in such a system exists many defects against the commercialization development. The following items are the major parts:

The first one is division into pieces because it is difficult to form a uniform market. In the example of the large-scale and middle-scale biogas project technology, as the large-scale and middle-scale domestic animal farms is in the possession of the local governments on the whole, it is the government that decide whether biogas projects should be created and even what their scale should be. After they are determined to be created, it is the local technology and research institutions relative to biogas projects, whose technical capability and level is advanced in the whole country or not is disregarded, that are above all taken into account. In general, units having more advanced techniques in other areas can not take part in it.

The second is the lack of the service system of commercialized society. Because the projects or enterprises, which mainly or even completely depend on the government's investment and run in a welfare mode, they do not take into account their economic profit and whether they get or lose money in business, and they pay no attention to their equipment's maintaining and service and moreover are short of promise and a feeling of responsibility for the user system's maintaining and service, which is evidently incompatible with the demands of the commercialization running mechanic.

The third is the decentralization of technical force which is resulted from their belonging to a department or system. In the planned economy system, the science and technique units respectively belong to different departments or systems, and the project tasks' assignment or commission is restricted by the interest of the departments or systems, that is to say, the idea of "earning profits by themselves" become the fundamental principle of assigning project tasks. For example, influenced by the principle that most biomass energy projects come from the department of agriculture and forestry, the industry department having strong technical force and other science and technique units are not able to take part in the

biomass energy projects, which is not favorable to the generalization of new advanced science and the development and prosperity of novel techniques.

The fourth is to make against the forming of the national technical standard and norm. Because every department and each area has its own standard and norm, it seems that the national standard and norm has nothing to do with the execution of project and techniques. This is also a main reason why the projects in different place are so different in their quality and running.

The fifth is to be not favorable to the voluntary interposition from finance system. In the planned economy system, the commercial banks and other finance institutions can not and are not permitted to participate in the development of the biomass energy technology, which is charged totally by the government, and as a result the resource of its fund is restricted and the finance institutions have no much idea about the biomass energy technology and have prejudice.

Therefore, to accelerate the commercialization development of the biomass energy technology and change its previous running mode, it is imminent to introduce the competition mechanism. In this respect, the English practice can provide us with some useful experience.

### **5.3.3 Creating special fund and running according to the market mechanism**

Such a mechanism puts forward to the fund indigence in field of the biomass energy technology. Its purpose is to raise the limited and disperse money to support the development of the biomass energy technology by means of low-interest loan and amortisation and at length achieve the objective of accelerating the development and enlarge its proportion in the whole energy resource market. So it is essentially subsidy of another form.

To implement special fund rolling development mechanism it is one of the key conditions to have a certain amount of capital fund. At present, such a capital fund can come from several optional and probable source: at first, it can come from fund bestowed by various international institutions or cooperation fund, such as the Global Environment Fund (GEF) and international cooperation fund; secondly it can come from the fund for removing the poor, the country electrification fund and funds appropriated by all levels of governments; the third is to collect the subsidy funds provided by different directions for the development of the biomass energy technology and use them uniformly; the fourth is to apply for State Department in

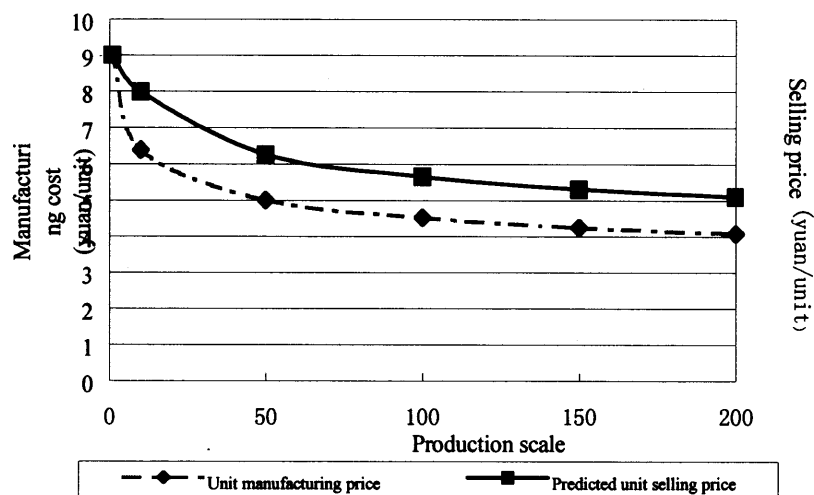
the special fund used to develop of the biomass energy technology and add a certain amount to the rural special energy fund, which has been amounted to 120 million Yuan, to support more forcefully the development of the biomass energy technology.

It has been proved by the practice of the rolling development fund that this measure is comparatively suitable for those expensive, low capacity apiece, dispersedly used biomass energy technology, e.g. intensified gas supply with straw gasification technology of the scale of a village. The cost of such type of technology is difficult to be cut down because the key problem - their scale is too small. But there are two ways in which their cost can be reduced: the first is to provide low interest loan for investors (manufacturer) to enlarge their production scale and then reduce their cost and extend the consumption market; the second is to provide a small amount of low interest loan to village governments to extend the demand of market and then to promote the activity of producers, enlarge production scale and cut down the cost.

Now taken as an example, the XFF-2000 central gas supply set using straw as its energy resource, was developed by the energy institute of Shandong province science institution, with it we illustrate the change and development of the production cost of gasification sets when the manufacturers have enough fund and enlarge the production scale.

According to the relation between the production scale and the production cost, we made estimation whose result is shown in Figure 5.3.

Figure 5.3 The predicted scale production cost of XFF-2000 straw gasification set



Except that the sale price of the first gasification set is the current practical amount, all other unit prices consider the necessary tax and rational profits, which amount to increase 25 percent of the previous production cost, and add to the production cost. For instance, if the production scale is 150 per year and the production cost is 42.4 thousand Yuan apiece, the sale price is  $42.4 \times 1.25 = 56.4$  thousand Yuan.

From the information above we can know that increasing the investment and support the manufacturer can stimulate the production, enlarge the production scale, reduce the cost and augment the profits. The gas collector and other apparatuses can also reach the same objective as gasification set, namely, with the aggrandizement of special production scale, the production cost will go down and at length result in the reducing of the production cost of the whole system, which then will be a truly commercialized product.

#### **5.4 Main Activities and Proposals for Improving Commercialization Development**

From the analysis above, we know that if the above policy conception can come into being to accelerate the development of the biomass energy technology, a series of practical actions and process should be adopted, which mainly include the following aspects:

##### **5.4.1 Design development layout**

On the basis of the completed biomass energy resource's procurability research, to analyze the development potential and the market potential with different techniques, to establish exploitation programs and plans of different techniques, and to make certain the exploitation steps, content and objectives.

##### **5.4.2 Strengthen technical warranty system construction, formulate the national technical specification and standard**

The national technical specification and standard is one of basic qualification of technology commercialization. Viewed from the current specific situation of biomass technology development in China, it is first to formulate and compile the technology specification and standard for large and scale biogas engineering and land fill gas generation engineering. It should to be worked out in limited period with intensive attention. In addition, it is also urgent to provide biomass energy research group, including the scientific service team, with profession education and

training, and should be done well.

#### **5.4.3 Update investment system**

Against the funds shortage in the current biomass energy technology development, it is necessary to generalize and analyze the experience of the domestic and foreign funds raising and management. And we also need to probe into the way of enlarging the financial resource and promoting the funds efficiency, continue to encourage multi-channel raising, call for setting up special funds and make them running and developing under the market mechanism.

#### **5.4.4 Study and establish the national relevant policies**

To study and establish both incentive and compulsory policies, both local and national policies, and meanwhile establish policies relevant to generalizing and applying industrialization and the commercialization of the important techniques.

#### **5.4.5 Introduce competition mechanism**

It is proved by more and more practices that although the development of the renewable energy resource technology such as the biomass energy technology may be baffled by technique and economy, the main obstacle is from the running mechanism. Because the technical difficulties encountered can almost be resolved by the modern science and technology and the problems in economy will be settled with the running mechanism (including idea and notion) changing, however it is difficult to ravel out the problems in mechanism which is entangled with such more extensive and more complicated problems as the national polity system, the economy system and so on. It is so much inconceivable to successfully implement the non-fossil fuel pact without reforming the whole electricity system in UK; it is also inconceivable to introduce competition and public bidding mechanism without the condition of reforming the national economy system in China.

However, because the change of social economy system only makes it possible to introduce new competition mechanism, a serial of work, which should be carried out to prepare for the running of the new competition mechanism, should comprise the following besides the four above.

- (1) To change our conception and break through the circumscription of departments and regions, and to encourage and mobilize more and more companies and

enterprises to take part in the competition of the biomass energy technology.

- (2) To pay more attention to propaganda and instruction. Through propaganda and instruction of various scales, make more and more people know about and support the development of the biomass energy technology and strengthen public resource sense and environment sense. So propaganda and instruction should be contained in the plan of the commercialization development of the biomass energy technology.
- (3) To enhance the cooperation and harmonization with the environment departments, the industrial technology departments and the finance departments and jointly accelerate the development of the biomass energy technology.

## ***APPENDIX I* Abbreviation**

AF	Anaerobic Filter
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
GEF	Global Environment Facility
GIS	Geographical Information System
GW	Gigawatt
IEA	International Energy Agency
IRR	Internal Rate of Return
kgce	Kilogram Coal Equivalence
kWh	Kilowatt Hour
LPG	Liquefied Petroleum Gas
M&I Waste CHP	Municipal and Industrial Waste Combination Heating Production
M&I Waste FBC	Municipal and Industrial Waste Fluid Bed Combustion
Mtce	Million Ton Coal Equivalence
Mtoe	Million Ton Oil Equivalence
MW	Million watt
NFFO	Non-fossil fuel Obligation
NPV	Net Present Value
OECD	Organization of Economic Cooperation Development
Pearson correlation coefficient	A coefficient shows the correlation of two variables, the more the value near to 1, the more the two variables correlated closely
R&D	Research and Development
SS	Suspended Substance
TS	Total Solid
UASB	Upper Flow Anaerobic Sludge Bed
USR	Upper Flow Solid Reactor

## APPENDIX II Reference

- 1 Biomass Energy Conversion Technologies in China: Development and Evaluation, MOA/USDOE Project Expert Team, China Environmental Science Press, Beijing, June 1998.
- 2 *Chinese Rural Energy Yearbook' 1997*. Editorial Committee of Chinese Rural Energy Yearbook, China Agriculture Press, Beijing, 1998.
- 3 NREL, Renewable Data Overview [2], Renewable Energy Annual 1997, Volume J. October 1997.
- 4 *Assessment of Biomass Resource Availability in China*. MOA/USDOE Project Expert Team, China Environmental Science Press, Beijing, July 1998.
- 5 DOE/ETA, *Annual Energy Outlook, 1997*. EIT, Oct. 1996.
- 6 *Economic Incentive Policy Study on China Renewable Energy Development, Workgroup of STEC*. China Environmental Science Press, Beijing, October 1997.
- 7 Jiang Wen, Promoting Quick New Energy Development by the Government Support. *Energy Policy Study*, Vol. 1, 1997.
- 8 *Energy Policies of LEA Countries 1997 Review*. OECD, May 1997.
- 9 SSTC-Directorate General for Energy of EU, Proceeding of Conference on China-European Union Energy Co-operation, Beijing, Oct. 13-15, 1996.
- 10 ENEL, Renewable Energy Sources in the Internal European Market, Proceeding of Milan Conference, 17/19 June 1996.
- 11 Jiang Senjie, et al., *Basis of Policy-making Studies*. China Social Science Press, Beijing, 1996.
- 12 Lin Dejin, et al., *Methodology of Policy Study*. Yanbian University Press, 1991.

**图书在版编目 (CIP) 数据**

中国生物质能技术商业化策略设计: 汉英对照/中国农业部, 美国能源部项目专家组编著. —北京: 中国环境科学出版社, 1999. 2

ISBN 7-80135-756-6

I. 中… II. ①中… ②美… III. 生物能源-应用-技术推广-市场营销学-中国 IV. TK6

中国版本图书馆 CIP 数据核字 (1999) 第 02522 号

中国环境科学出版社出版发行  
(100036 北京海淀区普惠南里 14 号)  
北京市鑫正大印刷厂印刷  
各地新华书店经售

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1999 年 1 月第 一 版 开本 787×1092 1/18  
1999 年 1 月第一次印刷 印张 10  
印数 1—1600 字数 179 千字

定价: 135.00 元 (CY)